The Engineer

MARCH 11, 1955 28 ESSEX ST., STRAND, LONDON, W.C.2 TWO SHILLINGS

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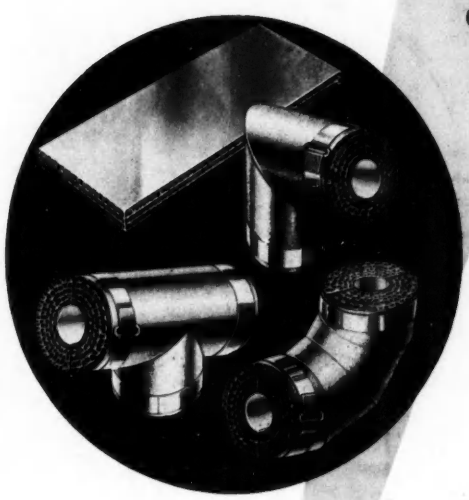

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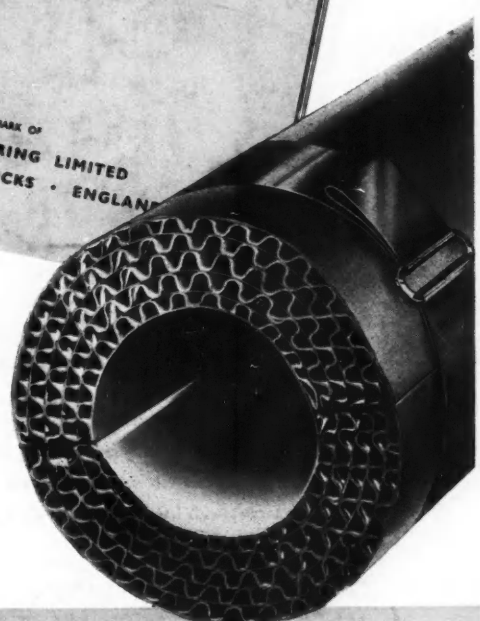

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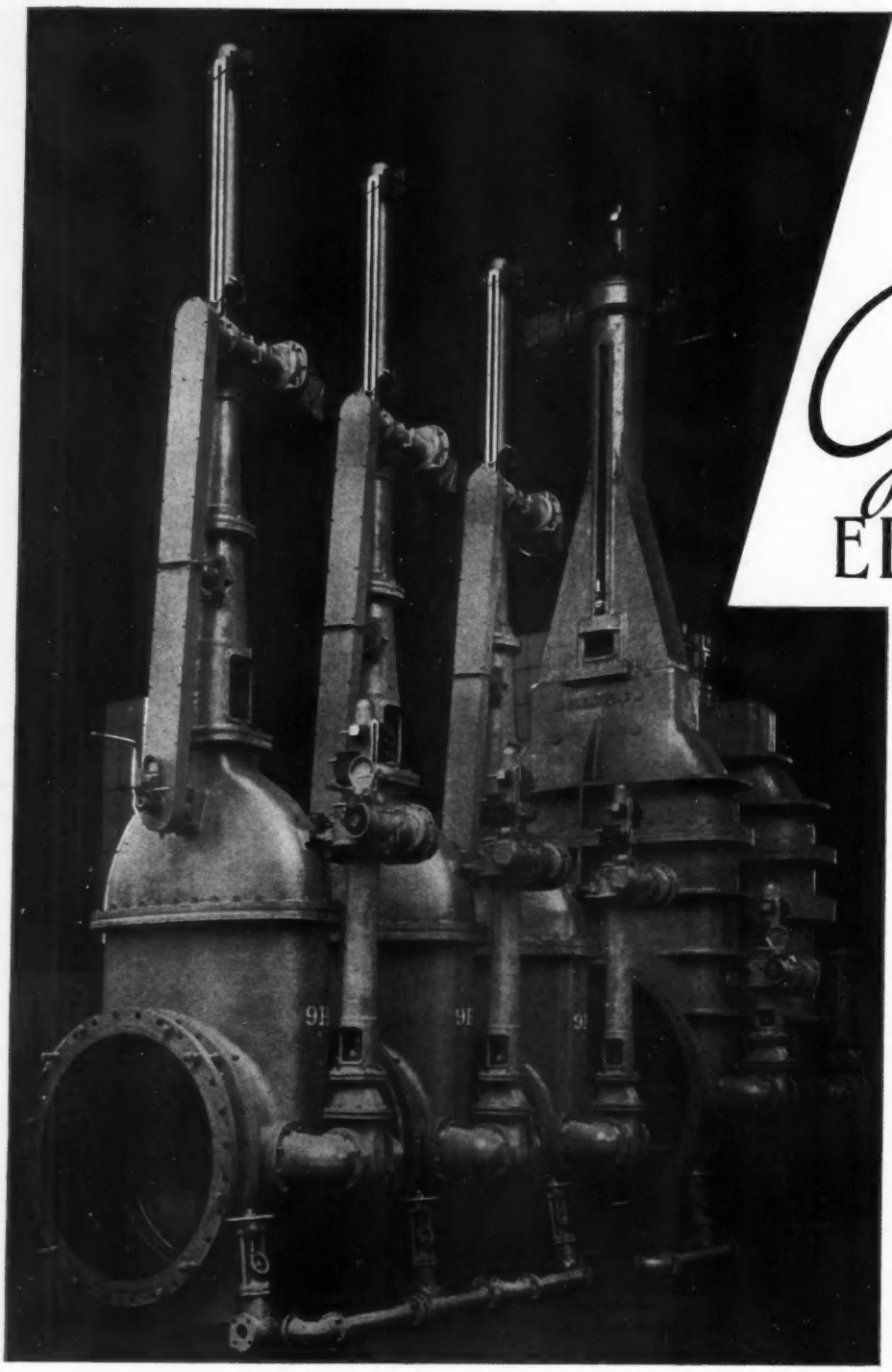

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THE ENGINEER

MARCH 11, 1955

N.P.L. Hydrodynamics Laboratory

ON the morning of Monday, March 7th, the chairman of the Froude Ship Research Sub-Committee, Sir William Stanier, F.R.S., cut the first sod on the site of the new Ship Tank to be built for the National Physical Laboratory at Faggs Road, Feltham, Middlesex. The new tank for ship model research will be 1300ft in length, on the main waterway, by 48ft in breadth by 25ft deep, and will be spanned by a carriage having a maximum of speed of over 50ft per second and control down to 1ft per second. The towing carriage, which will be of open tubular construction, is to tow models of up to 10 tons and will be driven by four twin-wheeled bogies, each powered by a 300 h.p. d.c. motor. A clear platform will be provided all round the carriage and a portable centre beam will carry all the dynamometer gear. This new research facility is necessary to meet developments in the speed of ships, with which the existing Yarrow Tank, measuring 550ft long by 30ft broad by 12ft deep, is inadequate to deal. To-day there is a need to study the question of "seakindliness" of ships and to assist in this the tank will be provided with a wave-making machine to simulate a range of sea conditions. About 10,000,000 gallons of water will be contained in the tank, which will have foundations laid on a gravel bed, and the whole will be enclosed by a light steel and aluminium-framed structure with external cladding of asbestos cement sheeting, and a lining of insulating panels. Steering and manœuvring experiments using radio controlled models, will be carried out in a steering and storage pond measuring 140ft by 100ft by 8ft deep. Associated with the pond is the model shop, which will be equipped for moulding, cutting and handling models up to 35ft long by 8ft beam. A water tunnel having a working section of 44in diameter and a maximum speed of 50ft per second, will be housed in a separate building, and pressurised. Propellers, cast in the foundry, up to 24in diameter, will be tested and the dissolved air content of the tunnel water will be controlled by an air resorber circuit. Lighting will be by cold cathode fluorescent tubes and special heating arrangements will be made to overcome particular problems of humidity and temperature. Power will be supplied at 6·6kV and a central boiler house fitted with boilers of about 10,000,000 B.Th.U. per hour capacity and using high-pressure water, will provide the necessary heat for the new laboratory.

Government Approval of L.C.C. Development Plan

IT was announced last Tuesday that the Minister of Housing and Local Government, Mr. Duncan Sandys, had approved, with modifications, the development plan for the Administrative County of London. In a letter to the L.C.C., conveying his approval, the Minister says that the plan will provide a sound and wisely conceived framework within which the life of London can continue to advance and develop in the years ahead. The Minister welcomes the Council's decentralisation policy, which aims to reduce congestion, but considers that the amount of additional land allocated in the plan to industry and offices is not wholly consistent with that policy and would worsen the congestion. He has, therefore, re-zoned for residential use some land which, under the plan as submitted, was to have been allocated for industrial, commercial or office use. The Minister also comments in his letter on vacated factories, saying that one of the essential elements in any policy for reducing congestion is to ensure that the factory premises of firms which decide to move out of London are not immediately reoccupied by other firms coming into London from outside. The most effective way of tackling that problem, the letter continues, is for the L.C.C. to purchase these factories, by agreement, as and when they become vacant. About roads, the Minister says that most of the schemes for new roads or improvements to existing roads, as indicated in the plan, have been approved, although, in a few cases, he has reached the conclusion, in consultation with the Minister of Transport, that some alternative scheme might be preferable to the one suggested. As a point of detail, the Minister observes that he is "not attracted by the title of Park Lane Boulevard," which is suggested for the fine new road between Hyde Park Corner and Marble Arch. Finally, the Minister mentions in his letter that he has given very special attention to the area in the City around St. Paul's Cathedral. He says that on examining the detailed plans and models of the proposed scheme he "could not help feeling that a unique opportunity was being missed to provide a truly worthy setting for Wren's world-famous cathedral."

Institution of Civil Engineers

THE current issue of the Institution of Civil Engineers' publication *Chartered Civil Engineer* announces that the late Mr. Graham Clark, who was secretary of the Institution for seventeen years, suggested that an annual lecture should be given on a subject of common interest to the members of the three major Engineering Institutions. This suggestion has been adopted and the lecture is to be named after Mr. Graham Clark; Sir Harold Hartley will deliver the first of these lectures on May 4th, and he has chosen for his subject "The Engineer's Contribution to the Conservation of Natural Resources." It is also noted in the *Chartered Civil Engineer* that the Council of the Institution does not reject original communications submitted to the Institution, on the grounds that articles on the project described have already appeared in the technical press. The Council sees no reason, it is stated, why engineers and contractors should be unwilling to give information on works, because of possible rejection on this account of any paper they may write.

Kariba Gorge Hydro-Electric Scheme

THE Prime Minister of the Federation of Rhodesia and Nyasaland, Sir Godfrey Huggins, announced last week that his Government had decided to proceed with the construction of the Kariba hydro-electric scheme, on the Zambesi River. There has been some controversy in the Federation, about which of the Kariba and the Kafue hydro-electric projects should be built first. Hydro-electric development in this area was investigated by a commission set up in 1946, which has since issued reports on both projects (THE ENGINEER, July 13, 1951, and February 13, 1953). Sir William Halcrow, Mr. H. J. F. Gourley, Mr. C. H. Pickworth and Mr. Geoffrey Kennedy served on the commission. It is considered that construction of both schemes will eventually prove necessary, we understand, but the choice of the most advantageous order of construction was complex; the Kafue scheme offered the possibility of power at an earlier date, but less firm power could be guaranteed than was thought desirable. Further investigations were undertaken by French consultants, and the present decision is subject to confirmation by the World Bank, and to an appraisal by Monsieur Coyne, the French authority. The Kariba scheme is envisaged in two stages, an initial stage of 385MW and a final stage of 1000MW; the proposals include a dam, at the upper end of the Kariba gorge, which would have a length of about 1400ft and a maximum height of about 360ft.

Royal Agricultural Society of England

EVER since its formation in 1839, the Royal Agricultural Society has been closely associated with the section of the engineering industry which specialises in the design and production of farm machinery and implements. For the past fifty years, the Society's headquarters have been at 16, Bedford Square, London, W.C.1. But with the progressive increase in its activities, the Society has found the accommodation there inadequate to its needs, and the council has therefore acquired the lease of premises at 35, Belgrave Square, S.W.1, where the floor space is nearly double that available in the Bedford Square house. It is stated that the move to Belgrave Square will be made at the end of the year. Another announcement made by the Society is that it has purchased a new grandstand for use at the Royal Show. The grandstand is constructed of aluminium and will provide seating for 6500 people. It will be erected for the first time at this year's Royal Show, which is to be held at Nottingham from July 5th to 8th. It is of interest to note that the programme of the farriery section of the Show is being expanded this year to include electric welding and a general competition of forge work with farm machinery. Finally, the Society has stated that its gold medal for distinguished services to agriculture is to be awarded this year to Sir James Scott Watson, who recently retired from the position of director of the National Agricultural Advisory Service.

Lloyd's Register Annual Report

LLOYD'S REGISTER OF SHIPPING has published its annual report, 1954, which notes the quickened interest in the efficiency of ships' structure and propulsion systems. The replacement of the older tramp tonnage by high-speed cargo liners of new design is mentioned, together with the possibilities of structural damage due to the effect of the design and increased speed. Finer forms, disposition of cargo and longer machinery spaces give rise to higher hogging stresses and affect longitudinal scantlings so that modified Rules have had to be introduced to take account of modern design. The report comments that the efficiency of longitudinal framing is now generally recognised and goes on to discuss welded construction and the Rule amendments touching upon structural details and the use of notch-tough steels, which are now to be employed in the main structure for thicknesses of less than 1in. In the light of recent experience structural modification has been recommended for a large number of existing ships, and the Construction Rules for welded tankers have been amended. With regard to shipbuilding steel, the report emphasises the need to use notch-tough steel for welded construction to resist rapid propagation of fracture. It is recalled, in the report, that a minimum manganese/carbon ratio was imposed in 1950 and that special quality steel was required for plates over 1in thick. These steels have been effective, but, it is stated, experience has shown that steel of the prescribed ratio is not a positive safeguard against brittle fracture, so that use of specially approved steels has been extended to thicknesses of less than 1in for main structural items. Mention is made of the oxygen-blown basic converter process to produce steel having properties comparable with Siemens Martin steel; the General Committee has given approval to such steel, although the steel is not accepted as a special quality steel for welding. Increased outputs of oil engines by pressure charging are noted, together with the present-day preference for the two-stroke cycle engine, and brief reference is made to free-piston gas generators, the gas turbine, steam reciprocating machinery and the steam turbine. One section of the report reviews modifications of the Rules and Regulations, and another gives notes upon the various research items under investigation at Crawley and Glengarnock, including work for non-marine interests, such as the British Atomic Energy Commission and the Ministry of Works.

Reports from the Footplate

By W. A. TUPLIN, D.Sc., M.I.Mech.E., A.I.Loco.E.

Officially sponsored accounts of observations made on railway locomotives tend to be stereotyped because it is convenient to follow certain conventions and imperative to follow others. In collecting quantitative information, the observer may fail to grasp the fundamentals of the problems that face enginemen and may not notice the details of their work in solving them.

REPORTS on rides on railway locomotives by amateur observers have become so numerous in recent years that discerning readers have developed critical faculties about them. One complaint about the conventional footplate story is that it gives no details of the enginemen's work, and another (delicately paraphrased) is that the standard tone of maternal approbation is scarcely apt. As one who has in this field occasionally conformed to convention, the writer feels moved to offer some defensive explanation in default of refutation.

In some footplate reports the locomotive is merely an incident in a flood of gossip, but those which purport to record factual information about the working of the engine are nearly all based on an article written by A. G. Robins and published in *The Railway Magazine* for October, 1899, under the title "A Run on the Wool-buyers' Special." The remarks about train services over the route concerned, the dimensions of the locomotives that have been used on it, the figures recorded on the run, the suggestions for meanings that the reader is recommended to attach to the figures, the comments on the scenery, and the slightly maudlin commendation of the enginemen, all now so familiar, are all there, having been conceived over fifty years ago. This was a notable article for its time and as it had slipped past official and editorial defences that could be expected to offer much resistance to such a pioneering effort, it was clearly something safe to copy.

Other circumstances made it not only safe but essential for subsequent reporters to adopt the Robins model. Most early articles on this subject appeared in the popular railway press and a curious characteristic of the average railway enthusiast is that he never tires of repetition but tends, on the other hand, to show a passionate resentment against anything that conflicts with established belief, or even departs from time-honoured phraseology. Editors of popular journals cannot ignore this trait and in the past one or them used to pander to it to the extent of suppressing any hint of originality and rejecting any phrase that could be replaced by a trite one even at the expense of accuracy. Writers hopeful of publication were obliged to fall into line and so was established a rote that any footplate reporter could follow and every reader came to expect. Such compulsion to mediocrity is not accepted by all writers and some of those who would have been the most virile and informative authors in this field remain unpublished because their technical integrity leaves them unconvinced that the cashier is always right; they decline to make capital out of the fact that the hackneyed circumlocutions are readily accepted by the popular press, while unsuspected truths are likely to be rejected in horror.

What makes the conventional reporting-plan overwhelmingly attractive to footplate-riders is the fact that it demands no skill or experience beyond the ability to read a watch or a gauge, and the composition of the report itself can be delegated to anyone able to produce a neat typescript on the basis of figures relating to the particular run accompanied by fulsome comment couched in tried and proved phrases. It is natural to take full advantage of this facility and if the resulting account has a feminine flavour the reader is as likely to be charmed as offended; if it is a little tedious it accurately reflects the feelings of a gauge-reader after the first half-hour of any run.

The really important happenings on locomotive footplates have only indirect connections with gauge-readings and may need some attention and discernment to elucidate; it is fortunate for the observer that convention makes no such demands upon him. The practice of limiting observations to pointer-readings has the advantage that it may still be pursued when the steam locomotive has been finally superseded (there may then in fact be more gauges to read) and so there need be no break in the flow of reports on footplate work even when it shall have been reduced to pushing buttons.

This (it is hoped) makes it clear that whatever its faults, established routine in footplate reporting is the result of co-operating with the inevitable. Like any other productive enterprise, it uses raw material obtainable in quantity at negligible cost now and for a long time ahead, subjects it to cut-and-dried treatment and passes the result on to consumers who might object to anything better.

Standardisation of any product makes for cheap production but sometimes fails to satisfy the discriminating user; here it leaves unanswered the questions of those who would like to know what has to be done to keep a steam locomotive running. These are reasonable questions because successful operation of such a machine depends largely on human skill and endurance and to such a small extent on gauge-readings that on steam locomotives it has never been found necessary to provide artificial lighting for any gauge but that showing the level of the water in the boiler. Only the enginemen themselves can tell exactly what they did and why they did it on any particular run but they may find nothing worth mention in a normal trip whereas they may remember exceptional ones very vividly. An observer might spend a very long time in riding on locomotives before experiencing such a run; even then, in the absence of personal experience in doing the work himself, he might fail to understand just what was going on, for the men would have no time to tell him and he, preoccupied with gauges, would have no time to listen.

Many enginemen do excellent work with the sole guidance of instinct born of experience; of those who can give logical explanations of their procedure, only a few have expressed themselves in saleable English. One way of obtaining a picture of what footplate work may mean is for someone who has done it to obtain from an engineman an account of a trip that he has cause to remember, resolving any apparent inconsistencies by unobtrusive cross-examination and relating it in logical order. Personalities may affect practical procedure, for there is no one and only way of driving or firing any engine and there are many ways in which the running conditions may differ from the humdrum routine that arithmetical reports suggest. An incidental advantage of a report from an engineman is that it comes naturally in strong Anglo-Saxon more appropriate to the rude punch and power of the subject than is the conventional idiom which, it must be confessed, approximates to a blend of Felicia Hemans and Godfrey Winn.

Getting to Grantham

We had a run-down A4 (said the driver) for a trip from King's Cross to Grantham, and my mate was a young man with no experience of main line passenger trains, although he had done some work on fitted freights. He was willing to learn, and not like some of those who came out of the Services just after the war; you couldn't tell them anything.

The first thing I said to him as soon as he came to the engine was that I didn't want her to blow off at the Cross. I let him feel how stiff the regulator was and said that with a thing like that nobody could stop her from slipping if she had 250 lb of steam in the boiler. I wanted to start with 210 at the most, and we did not want any priming and so we should begin with the boiler water halfway up the gauge glass.

It was a greasy day just before Christmas and so we made sure that the sanders would work and hoped that they would not fail before we got to Holloway. I turned them on as we backed on to the train and my mate had judged the fire nicely as the gauge was showing about 200 lb ten minutes before starting time.

We blew up 20in of vacuum in the train-pipe, but you never know how much the engine that brought the stock into the Cross may have created, and the brake will drag wherever there is a chamber still holding a higher vacuum than 20. There is always a chance of this, as it saves the empty-stock men some trouble if their vacuum is higher than any main line engine is likely to have. So I sent my mate back along the track to release the brakes on every coach and that cleared one drag that might have hindered us.

There were a lot of passengers on the platform and just before starting time somebody decided that we had to pick up three more coaches making sixteen altogether. So they uncoupled us and my mate turned the blower on and picked up his shovel. I stopped him, and he asked "Won't she need to be blowing off to take sixteen?" I told him "No! She can slip in that tunnel with 200 lb whether she's got six or twenty-six behind her. Leave your fire till we get away. Then rake it over and level it as fast as you can and shut the door tight till we are through the first tunnel."

We picked up the three extras and as it happened we were shunted on to the down fast line to get them back on to our train. So I ran well into the tunnel, sanding all the way out and back. We are not supposed to use sand if we can help it on track circuits, but we have to get trains moving and if track circuits won't work with sand, somebody should find something that will.

It was well past our booked starting time when we got back on to our train and then we found that we could not get enough vacuum for a brake. We could only sit and wait till the Carriage and Wagon staff put things right and that took about five minutes. I told my mate that this sort of thing could happen any time and so it is best not to do anything to the fire until you actually start.

We got away without any trouble on the downhill* bit into the tunnel, with the

* Not shown on published gradient profiles, but apparently about 1 in 80.

sanders and the blower working, my mate raking the fire and myself pulling her back one turn of the reversing handle from full gear and setting the regulator to what I suppose you might call about half open. All you can do is to try and judge from the strength of the beat how near she is to slipping. You have the best chance of controlling a slip if you keep the amount of steam in the superheater down to what will make her pull hard enough with a late cut-off. You can get up a good speed before the train is clear of the platform, but as it runs on to the rise through the tunnel she will slow down. This is only to be expected, but if you panic about it and open up a stiff regulator she is likely to slip. So it is best not to hurry. If she slows down too much, drop her into full gear and open the regulator a bit by pulling the handle with one hand and thumping the far side of it with the other till you feel it move and hear a stronger beat. Then notch up one turn and see how that goes. The reversing gear gives a reserve that you can control far better than a stiff regulator.

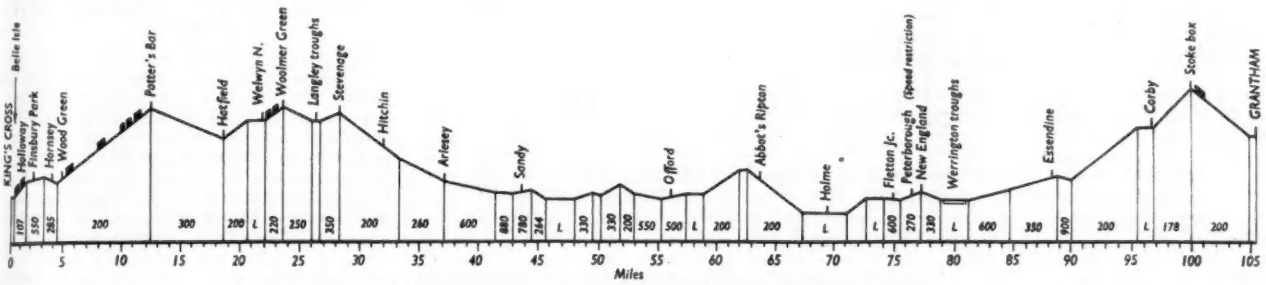
She made no sign of a slip but just chugged through the tunnels without breaking any records for speed. I have made better time that were dancing and then to start a regular round.

" One shovelful in each corner, one in the middle of each of the four sides, two at the back to right and left of the door, and one on each side a quarter of the length ahead of the corner. Then cover any holes or dancing places, go round again, and so on. Aim at the walls and they will scatter your coal." I took her easily up to Welwyn North to give him a chance to build his fire up. I opened her out in the second tunnel and as she only threw a few sparks I knew that he was getting near the mark and so I told him to stop firing and count fifty after every twelve shovelfuls. I said " Don't waste movements. When you have just fed a back corner, turn your shovel over and as you bring it out look under it for holes or thin places. If you get a cake starting anywhere, break it with a couple of lumps. Don't let your fire get thick at the front."

He complained that he was finding the fire too hot for his hands when working the shovel round to feed the back corners. This showed that he was used to haycock fires with black tops and not to really hot time. I could not tell him how late we were as I had no watch with me, but there was no need to worry about time as we should be late at Grantham whatever we did.

I told him he might do some good by breaking coal. If he could find a really big piece he might put it in the right-hand gangway so that he would not have to chase loose coal along the flap-plate, but he should break all other lumps. I said, " She'll not steam on slack or lumps to-day ; she wants it just right." At Sandy, I told him to count 120 after every twelve shovelfuls and to keep the firedoor shut whenever he could. A train will run fast enough for comfort on this stretch without pressing the engine very much, but after Offord she has to pull harder, and so as we went through I told him to count eighty after each round of twelve shovelfuls and I opened her out half a turn on the reverser. You naturally work in half-turns so as to keep the handle out of your way ; in some positions it sticks into you if you move in your seat.

When we passed Abbott's Ripton I said he could rest till we were by Holme. He told me he had never had such a hot fire, but still she was not steaming. I said,



Main gradients—King's Cross to Grantham (Eastern Region of British Railways)

to Holloway, but we did keep going. We came out of the tunnels with clean front windows and you are lucky to do that even when you have not let the engine slip. The blast usually brings soot down from the roof of the tunnel and then you have to go outside and wipe black mud off the windows if you want to see through them.

I opened her out as soon as the greasy rails would let me, but she seemed sluggish up to Finsbury Park. We had distant signals " on " through Hornsey and we were stopped at Wood Green ; what they were doing to manage that, I don't know.

There my mate told me that she was not steaming. Pressure was down to 160 lb and so I had a look at the fire. He must have been shovelling all the way from Belle Isle as he had filled the back half of the box up to the door and a lot of the coal was black and not much more than smouldering. I told him he had put enough on to take her to Edinburgh, but she could never breathe through such a poultice. All he could do was to level the fire out again with the pricker and leave it alone to burn down to something sensible while keeping the boiler water below the halfway line. I said, " If you have any trouble with injectors, give me a shout. I'd sooner stop before dropping the plugs than after." We got away again very slowly and took a long time to Potters Bar with pressure building up to nearly 200 lb as the fire burned clear.

I kept her pulling down to Hatfield, but as steam had gone back to 180 I had a look at the fire. My mate had left it alone as he had been told and it was now white, but too thin, dancing in many places and with two separate holes through it. So I told him to fill the holes, cover the parts fires. As we were well behind time we were bound to do all we could and so we had to find some way of helping him to stand up to the heat. I tied a hand-cloth to his left wrist so that he could cover the back of his hand with the cloth while firing. This worked fairly well, but he soon found that he was getting burned at the back as he bent down to pick up coal from the tender, which is pretty close to the back of the boiler of a Gresley " Pacific." I told him to try firing right hand and left hand in turn, but as he had never practised left-hand firing before, he did not have much success with that. So as a makeshift he fastened his thick jacket round his waist to form an apron behind him, and with that he managed to keep going. In the middle of all this we nearly missed Langley trough, but I dropped the scoop in time to get about 800 gallons.

The engine must have been steaming badly, as even with all care to keep a hot fire, pressure kept at about 200 from Woolmer Green to Stevenage. When we were getting near Hitchin I called him to me and said, " Leave her alone for a bit now and hold tight through Hitchin. We've got to let her go down here. She'll run to Sandy on the fire she has." I shut the regulator down to half and away she went down the bank. The crossings at Hitchin fairly rocked her and my mate's cap blew away as his head lurched out into the wind. I told him not to be upset about it ; most of us have lost caps at one time or another.

She rolled a lot down past Arlesey and when my mate saw the speed indicator at 95 he asked me were we not supposed to keep below 90. I told him we were supposed to do lots of things that we did not always do, and one of them was getting to Grantham on " ' Pacifics ' usually get hot if you fire them properly and I don't care whether she steams or not so long as she keeps going like this ; isn't it fast enough for you ? " He grinned at that as we were doing about 80 before we got to Holme, where I said, " Count seventy after twelve till I shut off at Fletton. Then keep your door shut till I tell you to start again."

I made a sharp run into Peterborough, finding the brakes good and strong on a dry rail. I forgot to look at the station time as we went through, but steam had come up to 220 lb and she still held it as I pasted her out past New England. So I kept her at it and told my mate " Count fifty after every round of twelve and keep all dancing places covered. Don't forget the trough."

After we had picked up water and were really moving again with the old girl hard at it, my mate said that the fire was dancing somewhere all the time, and so I said, " Well, you'll have to keep firing all the time. I'll give you a hand in a minute or two."

After we had passed Essendine I said to him, " I'll fire from every starter till you see the next distant and you take the rest of the time. Let's see what we can get out of her, but I want to catch every signal myself." So I gave her another half-turn on the reversing handle and got down to it with the shovel. She was roaring and pounding like a hero and the heat of the fire scared my mate. He said, " You'll melt the arch or the bars or something ; she can't stand it," but I told him, " We'll run till we stop. Keep firing round the sides, but look out for thin spots anywhere and keep them covered. Don't worry. She'll take it."

The only thing I had any doubt about was the inside big-end, but you can usually

smell them before they give out and so it was worth risking. You get nowhere on these jobs if you worry about everything that might happen. My mate was right about the heat from the fire. I had to change hands after every half-dozen shovelfuls to stand it at all, and I could see why there are complaints from firemen who are more interested in comfort than good firing. I had told my mate to look for dancing places, but whether he could see anything I don't know. It was like looking at the sun. You might have seen a hole if there were one, but not much else.

Between us we must have done pretty well as her pressure went up to 225 lb before we passed Corby and so I risked another half-turn on the reverser. She beat us then, for we worked as fast as we could, but I think that the whole fire was dancing before we got to Stoke, and pressure dropped back to 200. The speed indicator showed nearly 60, but how true it was I don't know

Then we both sat down to cool off. My mate said, " If it's always like this, Grantham ought to be a lodging turn." I kept her going hard down to Ponton before shutting off and as the rails were dry I thought we could pick up a few seconds with a quick stop. All the boards were off so I let her go till my mate called out, " Don't we stop here ? " ; then I took a good long grip on the brakes and we stopped just past the platform end.

The station clock showed that we were about right time and I was as surprised as my mate, but I did not show it.

We were both glad to get off and I told the man who relieved me that she was pretty rough. I said, " She'll go all right, but you have to fight all the way with a thin fire and even then she won't steam."

As we went down the platform a gentleman stopped me and said, " This was a very good run, Sir. Your handling of the engine was masterly and your judgment of time was superb." What could I say ? You have to be polite. So I said, " Oh, it's easy enough it you have a good watch. These engines run themselves." His wife chipped in then with " My husband has been so excited at the way you made her sound sweet at the front end that I must mention it in the next book I write. It was quite wonderful." My mate was too surprised to say a word ; he was not used to passenger trains.

287kV transmission line tower in Kildala Pass, British Columbia. The towers are up to 140ft in height and consist of five 38in diameter aluminium tubes and a cross arm

Some Commonwealth and Foreign Civil Engineering Schemes

No. I

A brief review of some civil engineering developments in overseas countries and of their progress during 1954 *is given here. The article is complementary to " Civil Engineering in* 1954," *published in January, in which works carried out by British civil engineers in* 1954 *were reviewed.*

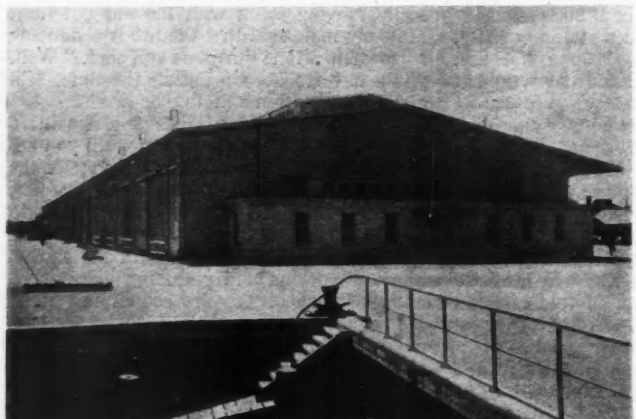
MUCH emphasis is placed, these days, by the governments of many countries, on vast development projects, based on civil engineering works. A preoccupation with raising the " standard of living " leads to a realisation of the important basic needs of a civilised community, which it is the civil engineer's task to meet. But in spite of the publicity given to many development projects, their rate of execution is governed by the general economic conditions of the country concerned, and in some cases an ambitious list of projects of this nature was found during 1954 to be making only slow progress, due to a rather unfavourable economic background, if not to actual technical difficulties.

A striking exception to these conditions was the progress being made in industrial expansion in Canada. Since the war, Canada has made great strides in increasing her material wealth and industrial strength, and an unprecedented industrial boom continued apace during last year. There was thus no check on the achievements of Canadian civil engineers, who had under construction several very large projects, which were being built at a great rate. The primary need, judging from the projects of which we have details, was for hydro-electric power, and a total of 1,758,450 h.p. of new capacity was installed during the year. The total installed capacity of Canadian water power plants was over 16,500,000 h.p., at the end of the year, representing a development of about 26 per cent of the estimated resources of the country.

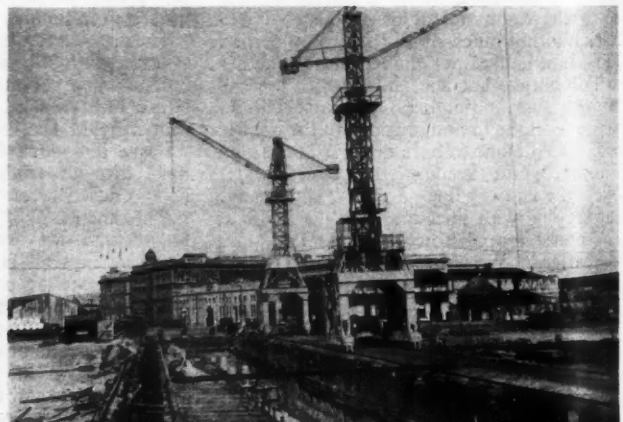
During the year, the Sir Adam Beck-Niagara No. 2 station of the Ontario Hydro-Electric Power Commission, which develops the head of Niagara Falls, was brought into operation. The ultimate installed capacity of this power station will be 1350MW, and there is a pumped storage scheme, totalling a further 235MW, associated with it. The first three 75MW turbo-alternator sets were put in service last August, and four more were expected to be in service by the end of the year ; there will ultimately be sixteen 75MW sets. Construction was started in 1950, and the main works were completed last year except for the installation of sets in the power house. Work was started on the pumped storage scheme last year, and this section of the project is expected to be in operation in 1956. A description of the scheme was published in THE ENGINEER of October 1st last.

The complete scheme of works on this length of the Niagara river also includes proposals for controlling the distribution of water at the Falls, and hence enhancing their beauty, even though substantial diversions are made for power production. The Hydro-Electric Power Commission of Ontario began construction in December, 1953, of the 1550ft control dam, which is situated on the Canadian side of the river, 250ft downstream from the existing submerged weir. The dam is being built in six stages, each stage involving the erection of a cofferdam, dewatering, excavating and concreting ; cofferdamming for the first two stages was completed last year. The final structure will comprise thirteen individually-operated bascule control gates mounted on concrete piers. Two gates, comprising the first stage of construction, are expected to be in operation in April, excavation having already been completed and concrete poured for the aprons and piers.

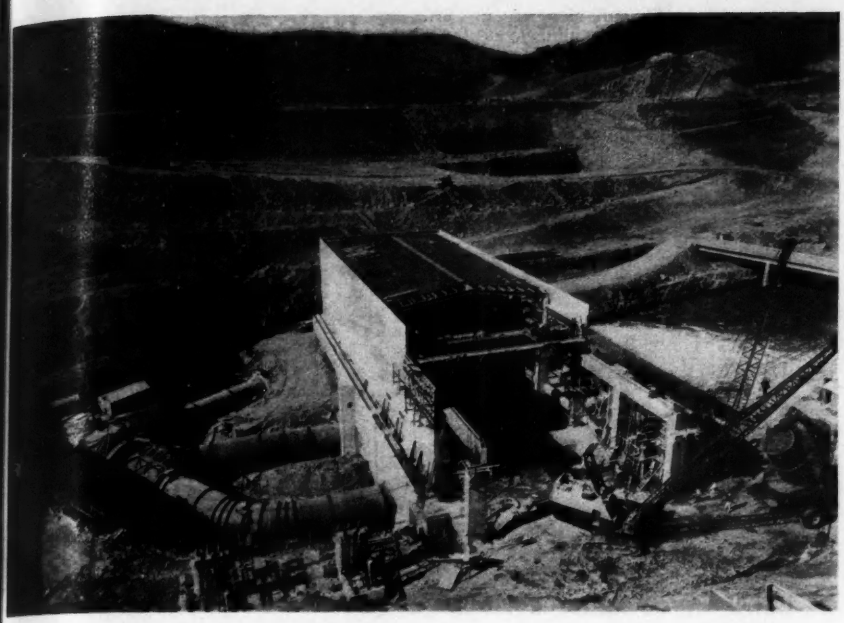
Final agreement was also reached on the long-



No. 1 berth transit shed at the port of Adelaide



Reconstruction of No. 6 berth of the inner harbour, Adelaide



Big Eildon rock-fill dam under construction. The dam is being built for the State Rivers and Water Supply Commission of Victoria

proposed international development on the St. Lawrence river and actual construction was begun on August 10th. The project, which is to be shared between the Commission and the New York State Power Authority, involves a main dam and power house between Barnhart Island and the Canadian shore and two control dams, one at the foot of the Long Sault Rapids between Barnhart Island and the United States shore and the other on the single main channel below Galop Rapids near the village of Iroquois, Ontario.

To dewater the power house site, two cofferdams of lengths of 500ft and 4500ft were under construction and will be finished by about the end of March of this year. Construction of two access tunnels under the present navigation canal, and of a Bailey swing bridge over it, was due to begin last December and construction of the power house will begin about next April. Tenders were called for the supply of 75,000 h.p. turbines, of which sixteen will be installed by the Commission, with the first expected to be in service in 1958.

Hydro-electric construction was also very active in Quebec during 1954, although comparatively little new plant was actually brought into operation. The Quebec Hydro-Electric Commission was actively engaged on its very large project on the Bersimis river, which is designed for 1,200,000 h.p. in eight units of which three are expected to be in operation in 1956. The scheme involves the building of a main dam 200ft in height at the outlet of Lac Casse, a tunnel 31½ft in diameter and 7½ miles in length, and an underground power house. Progress in 1954 included clearing, road building, camp construction, a new wharf at Forestville, a temporary power house of 15,000 h.p. at Lac Casse, and a beginning of the excavation for the tunnel and power house. The power produced initially will be used to serve the Gaspe peninsula by means of four 69kV submarine cables 31½ miles in length which were laid across the bed of the St. Lawrence river during the summer and autumn of 1954 and were under test in December, temporarily using power supplied by the Manicouagan Power Company. The construction of a 161kV line 132 miles in length from Les Boules to Copper Mountain was completed and the double-circuit 300kV line from Bersimis river to Quebec and Montreal is under construction.

Farther west, in British Columbia, the first stage of the Kemano-Kitimat project of the Aluminum Company of Canada (THE ENGINEER, May 29 and June 5, 1953) was completed in 1954. The first three Pelton turbines, each of 150,000 h.p. under 2485ft head, were brought into operation in the underground power house and power was transmitted at 287kV over the 50 mile line to Kitimat. Equipment was ordered and preparations are under way for the installation of the fourth 150,000 h.p. turbine and 122MVA generator for operation this year. The ultimate capacity is about 2,000,000 h.p. but no definite schedule of further installation has been announced.

The transmission line from the power station to Kitimat passes through the Kildala Pass, at a maximum altitude of 5300ft. Here thirty-five aluminium transmission towers, of up to 140ft in height and up to 2600ft apart, carry 9 miles of overhead cable. Because of the heavy snows, an ideally simple tower form was adopted by which the accumulation of snow and rime on the structure is almost completely eliminated. Because of the inaccessibility of the sites it was planned that each part should be flown in by helicopter and, for this reason, aluminium was the natural choice. Although a road was finally constructed to transport material the value of the design was shown, we are informed, by the fact that only 900 man-hours were required to erect an average aluminium tower against 2100 hours required for the steel towers. Typical loads on the towers are a total vertical load of 155 tons, a total horizontal load parallel with the line of 60 tons and a horizontal load due to change of direction of the line of 115 tons.

Each tower is composed of five tubular legs surmounted by a box girder cross arm, as shown in an illustration on page 332. All the tubes are 38in in diameter, the sheet thickness varying from $\frac{1}{16}$in to $\frac{3}{8}$in. The legs were made from unit lengths of 12ft 6in. This permitted the fabrication of each unit from two sheets (alloy 65S-T, the nearest English equivalent of which is HS10) roll formed into half cylinders and welded together, using the inert metal arc process, with a longitudinal permanent backing strip. Angle section joint rings were riveted to each end of these units, with the flange inwards, using aluminium rivets (alloy HR13) of up to $\frac{3}{4}$in diameter. The connection between two adjacent lengths was made by clamping the two adjoining rings together, thus allowing all the site joining work to be carried out inside the tube. The use of clamps reduced the bending of the jointing ring under tension loads.

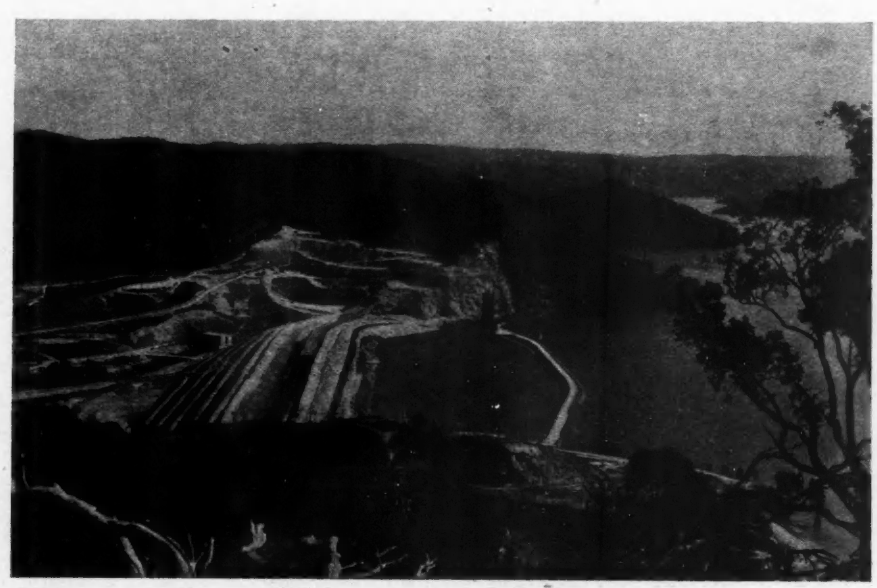
Manholes in the mild steel base shoes permit access to the inside of the legs where a ladder runs up the tube to another manhole in the mild steel headpiece. The ladder is thus fully enclosed and guarded against the elements. The realisation of this new form of transmission tower is the culmination of design work by Dr. K. Sutter of Aluminium Laboratories, Ltd., Geneva, and laboratory testing of large diameter tubes, with a full-scale load test on the prototype tower, in Canada. The theory underlying the use of the large diameter tubes was explained in a recent article in this journal.*

A similar scheme to the Kemano-Kitimat one, involving industrial development combined with hydro-electric power generation, but on a larger scale still, was announced during the year. It envisages diversion of the headwaters of the Yukon river southwards, at Atlin Lake, into the Taku river. It is estimated that a total power output of 4,300,000 h.p. could be obtained, which it is planned to develop in conjunction with metallurgical industries built beside the Taku river near the border of Canada and Alaska (see THE ENGINEER, August 20, 1954). These proposals have not yet reached a constructional stage.

AUSTRALIA

Civil engineering developments in Australia have, of late, been much more restricted by the country's economic climate than has been the case in Canada, but there is much of interest to record for 1954. According to a recent Reuter report, the first element of the Snowy

* "Large Diameter Aluminium Tubes in Structures," by C. Marsh, October 29, 1954.



Power station of the Big Eildon dam project. The scheme is primarily for irrigation, but hydro-electric plant of 135MW capacity is being installed

Mountains hydro-electric project (see THE ENGINEER, June 10, 1949) to be completed—the Guthega dam—was handed over to the hydro-electric authority on January 7th of this year. The dam cost £A9,000,000 to construct, it is stated, and it will supply a 60MW power station at Munyang through a 3 mile tunnel.

At the port of Adelaide, which is administered by the South Australian Harbours Board, extensive development schemes totalling £A23,000,000 are in progress. On page 332 we illustrate a transit shed at the newly reconstructed No. 1 berth of the inner harbour, which was completed in the 1953/54 financial year. The shed is 576ft long and 110ft wide with a roof with a central lantern ; there is a 20ft verandah covering a 12ft loading platform at the back. The shed is steel framed with corrugated asbestos cement cladding. Sliding steel-framed doors 18ft wide by 20ft high are provided on the wharf side, but on the shore side the doorways are in groups of three, comprising a central roller shutter door and two sliding doors, each 16ft by 18ft. The " Asbestolite " roof and the shutter doors were built by contract but the rest of the work was carried out by direct labour.

We also illustrate the reconstruction of No. 6 wharf of the inner harbour, where an old timber wharf was being replaced by a 450ft long wharf with a concrete relieving platform, similar in construction to the new wharfs previously mentioned. This reconstruction eliminates a " knuckle " and gives greater flexibility in handling vessels. By the end of the year all concrete work on No. 6 wharf was completed, and only the extraction of cofferdams remained to be completed. The wharf provides 27ft alongside at low water, and is served by two rail tracks on the wharf, and one behind the cargo shed, with a clearance line from adjacent sheds. A steel-framed cargo shed 432ft by 100ft is included in the scheme.

In the outer harbour gradual subsidence of the southern breakwater over the years and its ultimate submergence at high tides has necessitated the placing of a new mound on top of the original mound. This breakwater is approximately 1 mile in length and its restoration involves the placing of stones up to 10 tons in weight. This work was commenced late in 1953, by contract, and up to the end of the year the total quantity of stone placed amounted to approximately 100,000 tons. The work was then complete except for the placing of an additional layer of stone along the top of the breakwater for its full length ; approximately 110,000 tons of stone will then have been placed.

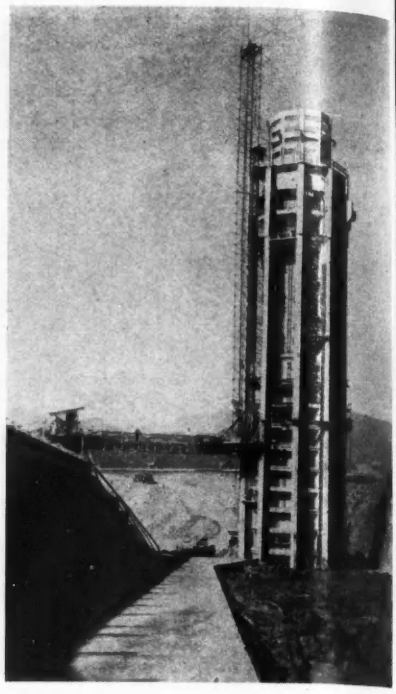
Good progress was also made with the construction of an additional berth for colliers at the Osborne coal handling plant. The construction of the concrete wharf was completed and the temporary steel sheet piling extracted from the cofferdams. During the financial year 1954/55 it is planned to complete the dredging of the berth and to extend the conveyor system northwards along the rear of the new wharf. This new concrete wharf is similar in design to those at berths 1, 6, 8 and 9, is 562ft long, and will have a dredged depth alongside of 28ft. l.w. with provision for an ultimate depth of 30ft l.w. The piled foundations for the rear wharf crane track and conveyor gallery running the full length of the new wharf, were driven during the year. Repairs were made to the existing timber pile foundations of the coal bins of the plant which had deteriorated due to dry rot and termite attack. The ground water level in the vicinity of the foundations was lowered by the well-point method of drainage, whilst the piles were cut off below normal ground water level and concreted to the under side of the concrete bases upon which the bin columns stand.

Big Eildon Project

A large dam is being built on the Goulburn river in the State of Victoria, about 90 miles north-east of Melbourne ; the photographs reproduced herewith show the progress made with it towards the end of last year. Big Eildon dam will enlarge a previously existing reservoir to 2,750,000 acre-feet to provide for additional irrigation and power development. The catchment area is 1500 square miles and water stored in the dam is to be released through the power station as required for irrigation and subsequently diverted from the river at the Goulburn weir 150 miles downstream. The embankment extends across the full width of the valley and consists of an earthen core supported with rock fill and gravel. The maximum height of bank will be 259ft, length 3000ft, and total volume of material 13,250,000 cubic yards, of which 5,130,000 cubic yards will be earth. Two dwarf cut-off walls ensure water tightness of the foundation rock-earth contact and form caps for the two 150ft deep grout curtains.

The spillway has been excavated behind the left abutment of the main embankment. This involved a rock excavation 260ft deep to provide a diversion channel during embankment construction at about the spillway level of the original dam. It leads to a concrete-lined chute and dissipating basin. As the embankment is raised above the old dam a mass concrete overfall dam 140ft high is being built at the top of the spillway chute. When completed, the spillway structure will have three vertical-lift, fixed wheel, spillway gates of 65ft clear opening and 21ft depth. Also there will be two 6ft 6in sluices through the spillway structure at a low level fitted with fixed wheel service gates upstream and 78in/68in needle valves with diffusers at their downstream ends.

Water will normally be drawn from the reservoir through trash racks on a reinforced concrete tower 236ft high, illustrated here. The tower has an internal diameter of 25ft 6in and is octagonal, with eight external stiffening ribs between which, at the base of the tower, are eight 15ft high ports which can be closed simultaneously by a 70-ton, 25ft diameter steel cylinder gate fitted with rubber seals. This gate hangs on a single pin chain. Individual ports can also be closed by external bulkhead sliding gates operated by two hoists built into a steel rotary roof



Intake tower of the Big Eildon dam project in Victoria. Eight ports at the base of the tower are to be closed simultaneously by a cylindrical gate 25ft diameter and 15ft high

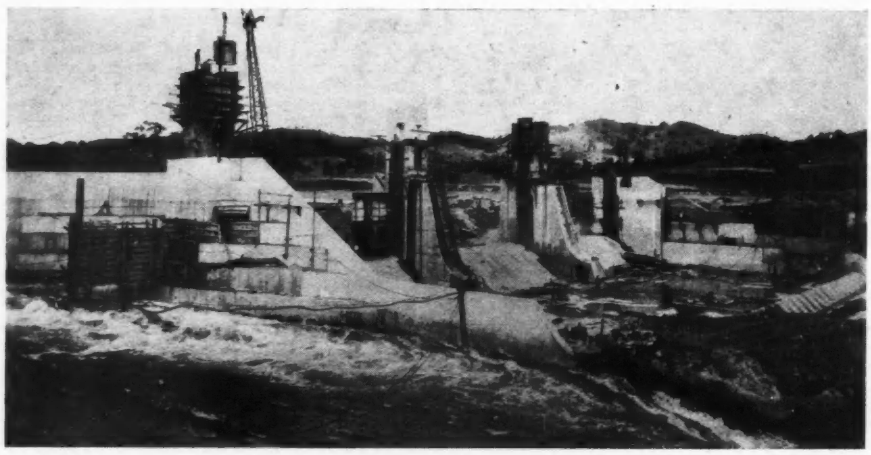
on the tower ; the hoists can also be used for removal of trash racks and operation of a trash rack rake. A man hoist is provided in the tower, together with a 10-ton crane for servicing the cylinder gate and its hoist.

Water from the intake tower passes into a 1270ft long, 23ft diameter, steel-and-concrete-lined shaft and tunnel, 28ft in diameter, driven through the Silurian sedimentary rock at the right abutment of the dam. The steel lining varies in thickness from $\frac{3}{8}$in to 1$\frac{1}{4}$in and was fabricated by welding into lengths of 21ft to 35ft, joined by hand welding in the tunnel. The space between steel and rock, averaging 2ft 6in, was filled with concrete pumped into place and consolidated by vibrators. Immediately downstream from the tunnel the 23ft diameter pipe branches into one 13ft and two 14$\frac{1}{2}$ 5ft diameter penstocks of lengths averaging 130ft. The small penstock leads to two 7·5MW turbines in the power station and each of the other penstocks lead to a 60MW turbine. The total capacity of the station is thus 135MW.

The power station will operate on peak load and, to avoid intermittent river discharge, a pondage weir (illustrated here) is being built about 3 miles below the main dam. It is a mass concrete overfall weir approximately 240ft long fitted with three fixed wheel steel crest gates identical with those of the dam spillway. The weir will have earthen wing banks about 8ft high on both sides of the river.

Ten million cubic yards were placed in the main embankment by the end of 1954; this progress brought the dam to a height of 180ft. The spillway excavation, chute and dissipator were completed and substantial progress was made with the mass concrete overfall dam at the head of the spillway chute, three blocks having been left low. The outlet works were complete except for the installation of gates and hoists in the outlet tower. The power house construction reached an advanced stage and the two small turbines were operating, but the large machines were not delivered to the site. Some 195,000 cubic yards of concrete had been placed of a total of 210,000 cubic yards required for the project. About 300 permanent houses were erected as it is hoped that the town will remain as the centre for a local industry. The dam has been designed by the State Rivers and Water Supply Commission of Victoria, which is also supervising construction. The Utah Construction Company of U.S.A. has the contract to execute the work.

(*To be continued*)



The pondage weir below the main dam will have three vertical-lift fixed wheel gates, each spanning 65ft and 21ft deep. The river diversion construction is shown in the foreground

Backlash and Resilience in Gearing and Structures

By H. CLAUSEN, O.B.E., B.Sc. (Eng.)*

This article is concerned with that class of structures, such as machine tools or geared mountings used for rotating masses, where the stiffness/inertia relationship becomes important. It describes tests carried out on a mounting locked at the training rack. Torques are applied cyclically, in increasing amplitudes to the motor spindle and the angular yield is plotted against acceleration. A mechanical hysteresis loop is obtained from which backlash, plastic yield and material stiffness can be separated. Different geared systems are then compared.

IN most engineering structures strength is of more importance than stiffness, and provided there is sufficient volume of metal to carry, as strain energy, the kinetic energy resulting from any likely motions, the stiffness/inertia relationship is not of great import. But it is necessary to ensure that natural frequencies do not resonate with any likely cyclic disturbing forces, external or internal, although, in general, the precise relationships between the forces arising during operation and the resulting yields are not a determining factor in design.

Machine tool structures and gearing are cases where these relationships are very important, and in the remote control of heavy structures by servo motors this overall structural stress/strain relationship becomes the dominating factor in design. Typical extreme cases occur in naval gun mountings, radar aerial structures, and directors, and this article deals with some recent work on them. The results are of general application, and are likely to be of interest in other fields.

* Late Chief Technical Adviser, Naval Ordnance Department, Admiralty.

Servo theory, dealing with backlash as a fixed quantity, and assuming that beyond the limits of backlash the stress/strain relationship between load and motor is more or less linear, indicates means for minimising the effect of these structural defects by modifying the control system, as for example, by the well-known "divided reset," which is, in effect, resetting from an adjustable nodal point in the resilient drive between motor and mounting. It assumes that the torque/yield relationship is reasonably linear.

Some years ago trials were started to find out what this relationship really was, and what its effects were, in various types of mountings in service. As experience grew, the method of carrying out the trials, and of presenting the results, developed into the form of a mechanical hysteresis loop, or a series of successive loops, on the precise analogy of a magnetic hysteresis test. The results are very illuminating, and their application has resulted in a revolution in servo performance.

For carrying out a stiffness test, the mounting is firmly locked at the training rack, and means are provided for measuring any yield of the locking arrangements. Torques are applied cyclically, in increasing amplitudes in both directions to the motor spindle, and the angular yield is recorded. Subtraction of the angular yield of the locking arrangements gives the yield, which, when plotted out as a hysteresis loop, enables backlash, plastic yield, and material stiffness to be effectively separated.

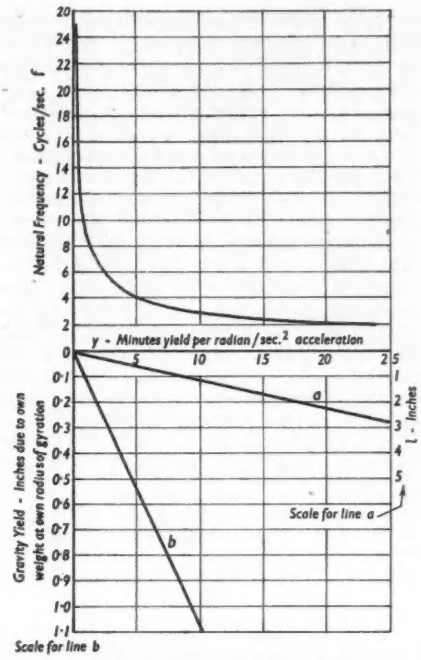

Natural Frequency - Cycles/sec. f
y - Minutes yield per radian/sec.² acceleration
Gravity Yield - Inches due to own weight at own radius of gyration
l - Inches
a
b
Scale for line a
Scale for line b

Fig. 2—Relationship between natural frequency, gravity yield and acceleration yield

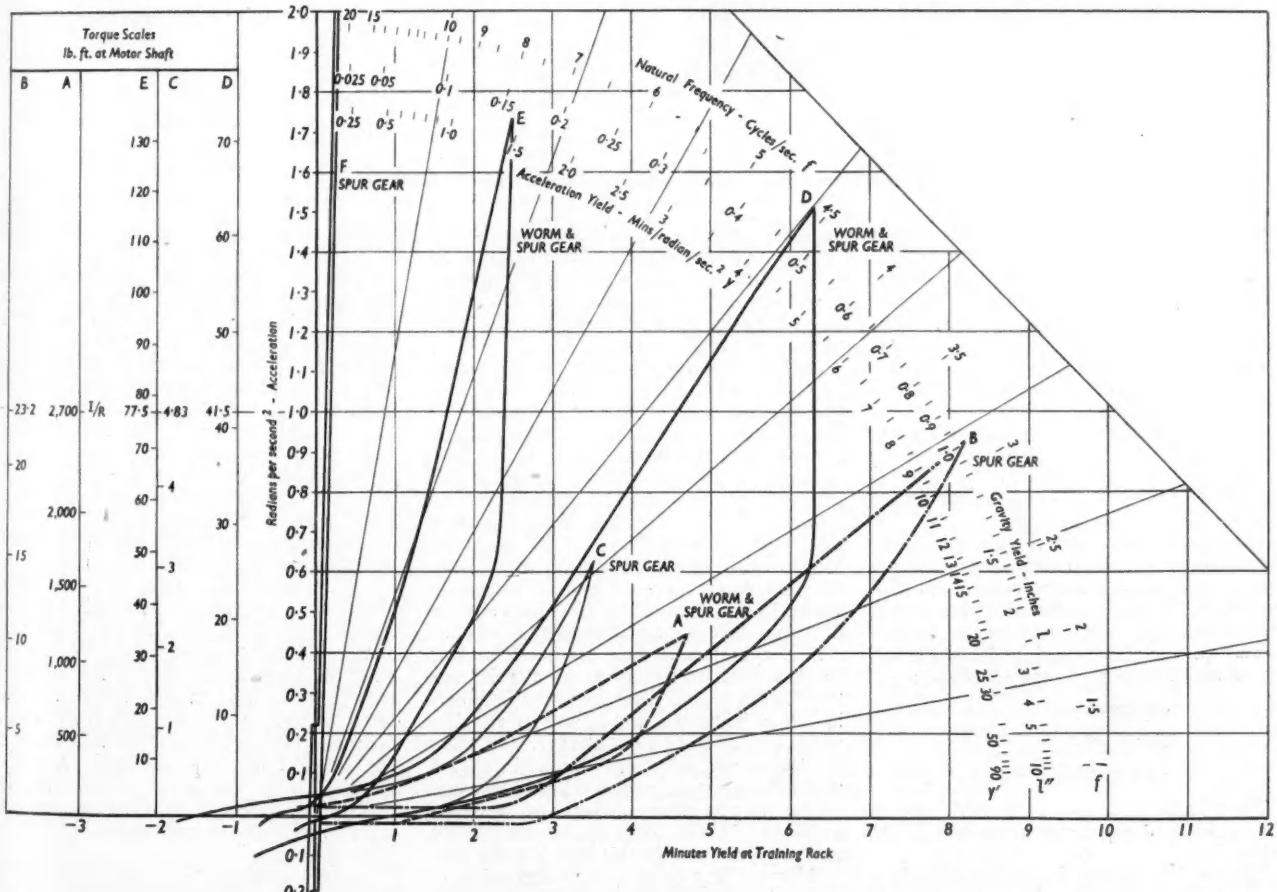

Torque Scales lb. ft. at Motor Shaft
B A E C D
I/R
Natural Frequency - Cycles/sec. f
Acceleration Yield - Mins/radian/sec.²
Radians per second² - Acceleration
Gravity Yield - Inches
SPUR GEAR
WORM & SPUR GEAR
Minutes Yield at Training Rack

Fig. 1—Stiffness test on gun mounting. The yield at the locked training rack is measured when torques are applied cyclically

Fig. 1 shows a number of typical loops from tests of actual mountings, referred to as *A*, *B*, *C*, *D*, *E* and *F*, in the approximate chronological order of design date. The torque at the motor spindle is converted into the corresponding mounting acceleration. If *I* is the moment of inertia in pounds, feet, seconds², and *R* is the overall gear ratio, *I*/*R* lb-ft torque is one radian per second² acceleration. Plotting the results to an acceleration/yield basis puts them in non-dimensional terms, where the performance of all different types of mountings can be directly compared. The examples shown cover a range of torque at the motor spindle, for the same mounting acceleration, of about 500 : 1. The loop shown at *F* is the only example whose design embodies the results of the work described in this article.

In a diagram of the type of Fig. 1, if the hysteresis loop can reasonably be represented by a straight line through the origin the mounting can be said to have the natural frequency represented by the slope of that line ; but where there are large ambiguities in the torque/yield relationship there is no real natural frequency at all. The diagram can be made to any suitable scales of acceleration and yield, and the scale for natural frequency comes out as follows :—

$(2\pi f)^2$=stiffness/inertia=acceleration/yield, so *y*, minutes yield per radian per second² $=3440/(2\pi f)^2$ (f=cycles/second)$=87/f^2$. If own weight applied as a torque at own radius of gyration *K* gives *l* inches yield, *g*/*K* radians/second² acceleration gives $l\times3440/12K$ minutes, or 1 radian/second² acceleration gives $l\times3440/12g$, i.e. $9\times l$ minutes of arc., and we get the following relationships between *y*, the acceleration yield (minutes per radian/second²), *l*, the gravity yield in inches, and *f*, the natural frequency in cycles/second :—

$$y=87/f^2=9\times l$$

$$l=y/9=9\cdot7/f^2$$

$$f=9\cdot35/\sqrt{y}=3\cdot1/\sqrt{l}$$

These relationships are plotted out in Fig. 2 for ready reference from one to the other.

The quality desired in the constructions under consideration has been described as "stayputness," and there seems no better word to describe the capacity of a structure to retain its integrity of form under the action of acceleration forces. "Stayputness" is, of course, the ratio of stiffness/inertia, and it can be defined in the familiar term of "natural frequency of oscillation," or of gravity yield, the extension of a simple spring mass system under its own weight (or, in the case of a rotary system, the linear yield, at the radius of gyration, due to a force equal to own weight applied tangentially at that radius), or in terms of the angular yield per unit of acceleration.

As regards servo performance, the natural frequency, as such, has very little influence ; resonance effects are not material. The serious matter is the acceleration yield, and also the ambiguity of the torque/yield relationship, both of which must be kept low. This implies a high natural frequency, but below a certain figure of acceleration yield, no useful purpose is served by raising the natural frequency higher. Acceleration yield is the important matter : natural frequency is perhaps the most familiar way of defining it, and gravity yield is often the most convenient way of measuring it.

Backlash in heavy gearing cannot usually be considered, as in instrument work, as a sum of mechanical clearances. Considerable force may be needed to overcome friction, and backlash is best defined as the motion, to and fro, on the input side, which will just—or just not—initiate motion on the output side. It is a single quantity, without sign, and if the first cycle of the hysteresis loop is only taken to slightly more than the slow creep torque it can be defined as shown in Fig. 3(*a*). If the next loop is taken down to a greater negative torque, as point *c* in Fig. 3(*b*), and then continued back to the first positive value, we get the distance "*a*" as the plastic yield due to the difference in torque between *c* and *b*, and so on. The whole loop may come out like Fig. 3(*d*), where friction is relatively high, or, as in Fig. 4, where the creep torque is too low to measure.

The largest loop defines an area of ambiguity in the torque/yield relationship, and any point within this area has the same validity as any other point, depending on the direction from which it has been approached. There are a surprising number of places in a composite structure where small yields may occur, if design is not carefully watched. The true material stiffness line will lie somewhere between the upper line of the loop, which gives stiffness plus friction, and the lower line, which is stiffness minus friction. An approximate stiffness line is shown dotted in Figs. 3(*c*), (*d*) and 4.

The difference in character of the loops between worm and spur gearing is very noticeable. That between loops *D* and *F* (Fig. 1) is startling, and the difference is reflected in the relative servo performance. *D* is a mixed spur and worm gear drive, with rather a low stiffness. The loop *F* is from a similar structure, but an all-spur-gear drive was used and particular attention was paid to stiffness in the design. Both structures are round about 8 tons rotating weight. The possibility of getting, in a structure of this size, a natural frequency of oscillation in training, with the driving motor locked, of between 20 and 30 c/s, is of some interest.

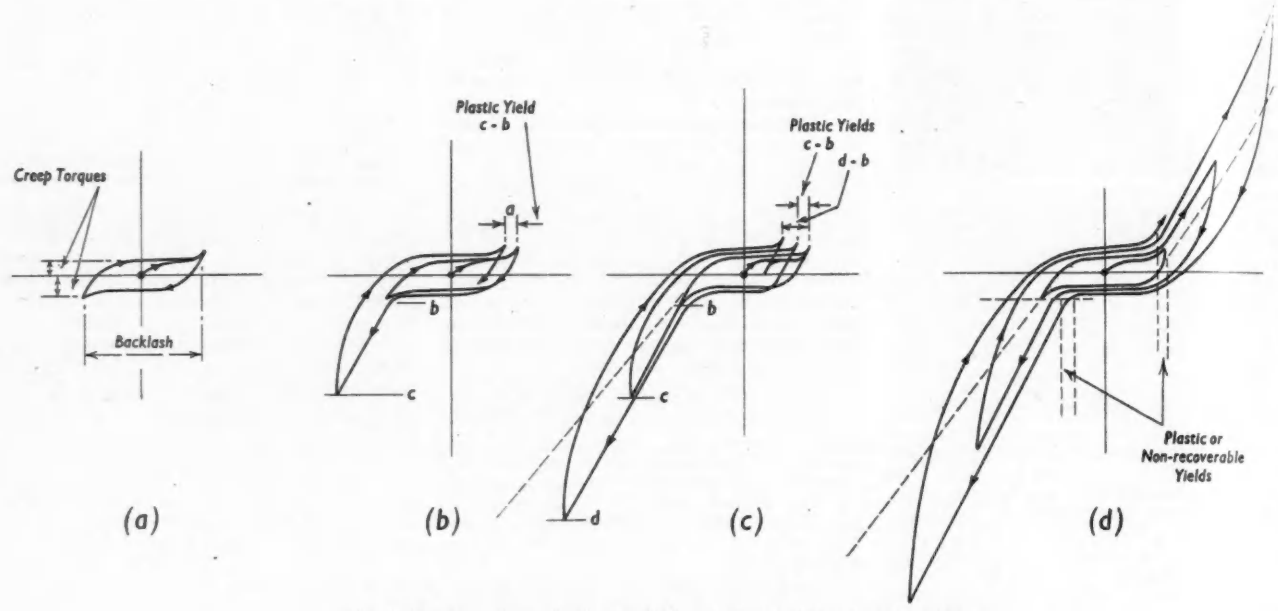


Fig. 3—Hysteresis loops showing backlash and plastic yield in heavy gearing

Contrary to what might be expected on first consideration, the friction of the worm gear of mounting *D* is of no benefit in improving servo stability. The energy loss per cycle at low amplitudes of motor oscillation is seen to be negligibly small, and the friction losses occur—most undesirably—only at high torques. The high-efficiency loop *F*, on the other hand, shows much greater energy loss per cycle at low amplitudes. Preloading gear meshes and bearings gives a useful frictional damping effect at small amplitudes without lowering the overall efficiency appreciably at high torques.

Experience of many types of drives shows clearly that the character of the stiffness/inertia ratio dominates the servo performance. If the "stayputness" is low the nominal power of the driving motor cannot be effectively used, and refinements in the servo control gear give only very limited benefits. With a high natural frequency, on the other hand, a good performance is possible with relatively simple circuitry, and the full benefit of improved performance is obtained from any refinements of the servo control system.

As an example of what one might aim at, 1 radian per second² is quite a high acceleration for a mounting of any size. One minute

yield as a result of this acceleration would be a very small error. One minute yield per radian per second² is 9 c/s (see Fig. 2). There may be little need to try to go higher, and there will probably be some difficulty in reaching this figure in mountings of any size. Directors can be, and have been, made with much higher figures.

As a first approach to a design, any performance programme will give a programme of acceleration. The relationship between the required acceleration and the maximum tolerable yield will give an acceleration yield, (minutes of arc per radian/second²). Inspection of Figs. 1 or 2 will give the corresponding natural frequency and gravity yield. If the weight of the rotating structure is assumed to be applied as a torque at the radius of gyration, with the driving motor locked, an

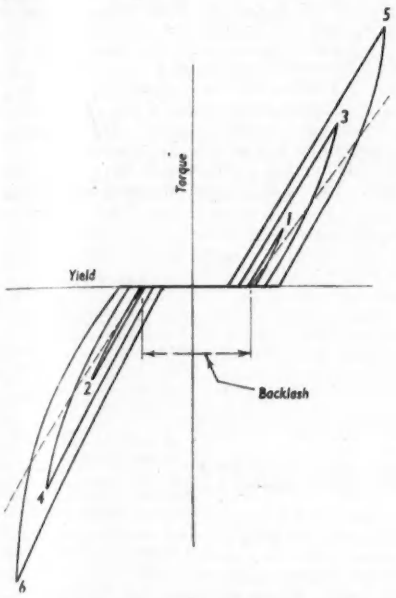


Fig. 4—Typical hysteresis loop where the creep torque is too low to measure

estimate can be made of the resulting linear yield at that radius. Some large structures, such as swing bridges, would probably collapse completely under these conditions, but proportionality can be maintained, i.e. if $1/n$th of the rotating weight be applied tangentially at the radius of gyration, either during a test or as an estimate, the resulting linear yield must be multiplied by n to give the gravity yield, from which the natural frequency, or "stayputness" of the structure, can be obtained on inspection from Figs. 1 or 2.

Hysteresis loops taken the other way round, by locking the motor and applying torque to the mounting, differ in shape from the normal ones to an extent depending on the efficiency of the gearing and the nature of the structure. Little work has been done on this as results do not seem to justify the increased difficulty of doing tests this way. By fitting strain gauges on the motor coupling shaft and electrical means of measuring the overall yield between motor and mounting and taking the two quantities to the plates of a cathode-ray tube, hysteresis loops have been taken under dynamic conditions of normal working. The changes in the shape of the loop are interesting, particularly in a case such as *D* of Fig. 1, when input frequencies make multiples of any natural frequencies in the system, but here, again, the results did not seem to justify much further effort. The main thing is to keep the loop narrow, as in *F* of Fig. 1—for example, where there is little or no room for changes in shape. This is a matter of good engineering design.

The range of designs involved in mountings, directors, radar aerials, &c., is so wide that it is not possible to show typical constructions, but the following elementary principles seem to be a useful guide where precision servo control is required :—

(1) The radius of the training rack should be about equal to, preferably larger than, the radius of gyration of the rotating mass, with a direct connection to the rotating masses at, or about, that radius.

(2) Gear wheels should be as large in diameter as possible and pinions as small as possible, so as to give the minimum number of gear meshes.

(3) Two separate training drives, arranged so as to give a pure turning couple, have many advantages over a single pinion drive, particularly where, as with some large roller paths, precision centring is not possible.

(4) Structural distortions, rather than "backlash" or torsional yields, may be the dominating factor, and any unbalanced couples arising from forces applied in one plane and resisted by stresses in another plane must be carefully watched.

(5) Normal securing arrangements such as keys, splines or fitted bolts are usually quite inadequate at the heavy end of the gear train, and some form of preloaded securing arrangement is usually necessary, both for securing gear wheels to shafts and for holding gearboxes in place. There are many such constructions available, some of them being modernised versions of the wedge arrangements used by James Watt and his contemporaries.

The matters dealt with are of an elementary nature, but the results are important and of wide application. The design of almost any machinery or piece of mechanism can usually be substantially improved from the evidence shown by a hysteresis loop test as described.

Permission to publish these results has been kindly granted by the Admiralty, and the writer, in acknowledging the help of many collaborators in the work involved, would like to single out Mr. R. N. Woodruff, of Vickers-Armstrongs, Ltd., Crayford, for his enthusiastic and effective practical help in the early experiments, where the principles which have since been followed were first tried out and confirmed.

Light Alloy Launch "Gannet"

For several years Universal Launches, Ltd., has been engaged in building aluminium alloy launches on the "Two-Way-Tension" system, which was described in The Engineer of February 23, 1951, in an article dealing with the survey launch "Ain-Al-Bahr." The various small craft built in the system range from 26ft to 60ft in length and include fast launches, passenger launches, patrol boats, yachts and survey craft. The latest addition to the company's range of designs is the 32ft light alloy launch "Gannet," seen in our photograph, which was exhibited at the National Boat Show and was demonstrated recently on Southampton Water. Several modifications, not previously incorporated in the construction system, have been included and the most important of them are the rounded fore foot, increased beam and additional flare forward, the latter item helping to throw water and spray well clear and so assisting to maintain a dry ship.

The "Gannet" has been designed to provide economical water transport for passengers and materials and the special system of construction provides a strong, light hull which is easily driven, thus ensuring low running costs. Low hull weight and engines of low power mean increased payload, and the launch, which has a length of 32ft 4in by 10ft 4in beam and a draught of 2ft 3in, has seating accommodation for twenty-two passengers and ample space for baggage. A large watertight compartment forward with access through a hatch on the foredeck provides stowage for the boat's gear and additional cargo.

Twin Parsons Ford "Ten" motors, mounted in sound-insulated casings lined with 1in "Acoustipad" and having all controls grouped together at the helmsman's position, provide the necessary power. In the light condition the launch achieves a speed in excess of 14 knots and can cruise at about 11½ knots with twenty passengers on board, the fuel consumption being approximately 3½ gallons per hour.

Light alloy passenger launch "Gannet"

It is estimated by the builders that if powered by a Perkins "P4" or a Parsons "Porbeagle" diesel engine a cruising speed of 10 to 11 knots could be obtained, with thirty passengers on board, for a fuel consumption of 2½ gallons per hour.

Aluminium alloy sheet and extrusions to Standard Specification N.5, supplied by the British Aluminium Company, Ltd., have been used in the construction of the launch. The hull plating is of 14 gauge and this thickness has been used for the bulkheads, keelson and superstructure sides. Sheet of 16 gauge forms the superstructure top and the fore and side decks consist of 12-gauge material, while the keel is a 2¼in by 2¼in by ⅜in tee section, and the frames of 2in by 1in by ⅛in tee bar. Three-bladed manganese-bronze-chromium plated propellers are fitted and the stainless steel propeller shafts are carried in "Tufnol" impregnated fabric bearings. Skegs cast in light alloy to specification L.M.10. W.P. are provided to enable the launch to take the ground easily without listing. The fuel tank is of welded construction and the equipment includes a 17-lb Danforth anchor.

The hull of the "Gannet" has been standardised by Universal Launches, Ltd., to reduce initial costs, but the superstructure and general arrangements can be modified to meet particular requirements, while the craft can be powered by a single or twin arrangement of petrol or diesel engines.

Engine Test Laboratory.—We are informed by the British Petroleum Company, Ltd., that a new engine laboratory, additional to existing plant, is being built at the research station at Sunbury, for testing motor fuels and lubricating oils. There will be a chassis dynamometer room and facilities for testing agricultural tractors.

Production of Fresh Water from Salt or Brackish Water*

By J. LEICESTER, M.I.Chem.E., A.I.Mar.E.†

It is the aim of the present article to survey the past, present and future trends of fresh water production and to illustrate how the efforts of the R.N.S.S. have helped to provide the sailor afloat with a supply of fresh water the equal of that of his colleague on land, how the efficiency of the fighting ship has been improved and, what is even more important, how the money spent on scientific research has repaid handsome dividends through improved operating efficiency and reduced cost of the water produced.

Conventional Types of Distilling Plant

A SINGLE-EFFECT distilling plant can be said to consist primarily of two heat exchangers, namely :

(1) The evaporator, in which heat is supplied to the sea-water and which converts some of this water into steam (or vapour) leaving salt impurities behind in the residual brine.

(2) The distiller condenser, in which heat is taken from the vapour which is thereby reconverted into distilled water.

All the other parts of the plant, such as pumps, valves and feed heaters, are supplementary to these two main components and are fitted either to enable them to perform their correct function or to increase the operating efficiency of the plant. Throughout this article the term "vapour" is used to signify the steam/air mixture released from the boiling brine and the term "brine" refers to the concentrated sea-water in the evaporator shell.

The single-effect evaporator possesses one shell only. Heating steam passes through a series of heating coils where it condenses and gives up its latent heat of condensation to the surrounding brine, a proportion of which is converted to vapour. The vapour then passes out to the distiller condenser where it condenses to form the product, distilled water. The vapour pressure in the shell can be either above, at or below atmospheric, according to the pressure of the heating steam available and the necessity for maintaining a temperature differential of about 70 deg. Fah. between that of the heating steam and the brine boiling temperature.

The multiple-effect evaporator is merely a number of single-effect units operated in series but instead of the vapour from the first effect passing directly to the distiller condenser, it passes to the heating coils of the second effect, and so on throughout the number of effects that may be in use. The vapour from the last effect passes straight out to the conventional distiller condenser. The shell pressure or vacuum decreases in each effect to maintain the desired temperature differential between brine and heating steam. The choice of single or multiple-effect evaporation depends upon a number of factors, the main ones being the initial pressure of heating steam available, the average daily output required and the space available for the plant. In general, the cost of water produced by a multiple-effect evaporator is less than that from a similar capacity single-effect plant, but this is offset by the increased size of the multiple-effect evaporator. Thus, for marine installations, where size and weight of plant are major considerations, single or double-effect evaporators are preferred. In land power station installations, where cost is a more important consideration than space, it is found that quadruple and even sextuple plants are quite common.

Another design of conventional evaporator, the forced circulation flash evaporator with a steam thermo-compressor, is in quite common use in land power stations, but it is not favoured for marine use. The main advantage claimed is increased thermal efficiency coupled with reduced cost per ton of distilled water. However, to achieve this, the plant becomes more complicated and, what is even more important, the present design of heater with brine inside the tubes is very prone to scale formation from the concentrated brine. Once scaled up, this heater is very difficult to clean on board ship.

Scale Formation and its Effect on Evaporator Efficiency

On an average 1 ton of sea-water contains about 70 lb of dissolved salts, consisting almost entirely of the chlorides, sulphates and bicarbonates of sodium, calcium and magnesium. Sodium chloride accounts for about 78 per cent of these salts, and calcium and magnesium 1·2 and 3·7 per cent respectively. Under evaporator operating conditions sodium chloride forms little or no scale due to its high solubility, whereas calcium and magnesium deposit scale due to the formation of insoluble compounds. This scale deposit consists mainly of calcium carbonate, magnesium hydroxide and calcium sulphate. The proportion in which these compounds appear in the scale, their crystalline form, texture, hardness and resistance to heat transfer, largely depends upon operating conditions and may show considerable variation.

As evaporation proceeds the concentration of solids in the brine increases up to the point at which the brine density is normally maintained (equivalent to a concentration twice that of sea-water, i.e. 20 deg. Admiralty), and when the concentration of any particular salt exceeds its solubility under these prevailing conditions, it crystallises out of solution. When a bubble of steam is formed on an evaporating surface, the salts contained in the surrounding water concentrate in a thin liquid layer around the bubble periphery where this is in contact with the metal surface. This surface, in contact with the vapour in the bubble, becomes slightly superheated and the extra heat causes increased evaporation at the contact edges of the bubble. If the liquid at this point is saturated, e.g. with respect to calcium sulphate, then the increased evaporation produces supersaturation and an irregular ring of calcium sulphate crystals will be deposited. If, after a bubble is released from the evaporating surface, water unsaturated with respect to calcium sulphate replaces it, the crystals will redissolve, but if saturated water replaces the bubble, they will continue to grow and so scale will gradually build up on the heating surface.

Some of the magnesium and calcium in solution in sea-water is in the form of magnesium and calcium bicarbonate. When the water is boiled, carbon dioxide is driven off and the bicarbonates are converted into carbonates. Calcium carbonate is insoluble, but magnesium carbonate is soluble and further boiling gradually converts it into an extremely insoluble compound, magnesium hydroxide. This compound, together with the calcium carbonate, forms the basis of most evaporator scales. These reactions may be indicated as follows :—

(1) $Mg(HCO_3)_2 = MgCO_3 + CO_2\uparrow + H_2O$.

(2) $MgCO_3 + H_2O = Mg(OH)_2 + CO_2\uparrow$.

(3) $Ca(HCO_3)_2 = CaCO_3 + CO_2\uparrow + H_2O$.

As previously mentioned, the composition of the scale formed at the heating surface is mainly dependent on the conditions under which the evaporator is operated. The accompanying table spans the cause and effect of major variations in operating procedure.

It will be seen that for any feed water treatment to be successful it must be effective whether the scale is composed mainly of calcium carbonate or of a mixture of calcium carbonate with magnesium hydroxide and/or calcium sulphate.

From the weight of the solid potential scale-forming material present in the concentrated brine it will be obvious that scale formation in an evaporator handling some 10 tons per hour of sea-water feed is likely to be considerable. With untreated sea-water it is quite common during a 500 to 600 hour operating period for a hard adherent scale layer of ¼in thick to form over the entire heating surface. This results in a considerable loss of efficiency because the layer of scale imposes a very serious resistance to heat flow. Taking as average an overall heat transfer value of 900 B.Th.U. per hour per square foot per deg. Fah. in an evaporator with clean copper heating coils, the formation of scale over a 500 hour operating period can reduce this value to as low as 300 B.Th.U. per hour per square foot per deg. Fah. with the obvious associated drop in the output of distilled water per square foot of heating surface.

Effect of Major Variations in Operating Procedure

Evaporator shell pressure	Brine boiling temperature	Brine density (sea-water = 10 deg. Admiralty)	Coil (heating) steam pressure	Composition of scale formed
Vacuum ...	Below 212 deg. Fah. ...	Low, 15 deg. Admiralty	Low (4–15 lb/sq in gauge) ...	Mainly calcium carbonate
Vacuum ...	Below 212 deg. Fah. ...	High, 30 deg. Admiralty	Low (4–15 lb/sq in gauge) ...	80 per cent calcium carbonate 20 per cent calcium sulphate
Atmospheric	212 deg. Fah.	Low, 15 deg. Admiralty	Medium (16–28 lb/sq in gauge)	80 per cent calcium carbonate 20 per cent magnesium hydroxide
Atmospheric	212 deg. Fah.	High, 30 deg. Admiralty	Medium (16–28 lb/sq in gauge)	60 per cent calcium carbonate 20 per cent magnesium hydroxide 20 per cent calcium sulphate
Pressure ...	Above 212 deg. Fah. ...	Low, 15 deg. Admiralty	High (29–60 lb/sq in gauge) ...	50 per cent calcium carbonate 40 per cent magnesium hydroxide 10 per cent calcium sulphate
Pressure ...	Above 212 deg. Fah. ...	High, 30 deg. Admiralty	High (29–60 lb/sq in gauge) ...	30 per cent calcium carbonate 20 per cent magnesium hydroxide 50 per cent calcium sulphate

Foam Formation and its Effects on Evaporator Efficiency

Sea-water entering the evaporator shell is brought into contact with the steam-heated coil surface and rapidly reaches the temperature of boiling. When pure water is boiled the bubbles of steam rise to the surface and burst. However, when a brine solution containing much dissolved solid matter and possibly including traces of organic matter is boiled, foam is formed on the surface of the liquid, and if the rate of vapour generation is sufficient the whole becomes a foaming mass in which it is impossible to define the precise point of separation between brine and foam. It will be appreciated, therefore, that control of the foam level becomes a very difficult matter, because the false head of foam does not register as a true level in the gauge glass. It can only be controlled by direct observation through the sight glass in the side of the evaporator shell.

As the vapour is released from the foam surface, large masses of brine are thrown upwards and they break into droplets of varying mass and diameter. The height to which these droplets are projected is directly related to the rate of vapour release from the foam surface. If the evaporator design is such that there is sufficient height between foam surface and the entrance to the baffle, no brine particles will reach the baffle by direct splashing. However, once each splash has broken up, the individual droplets then come under the influence of the

* Issued by the Chief of Naval Information, Admiralty. Extract.

† Royal Naval Scientific Service, Admiralty Materials Laboratory.

velocity of the vapour passing up the shell of the evaporator. Particles above a given size will, due to their mass, drop back into the brine; whereas particles of smaller mass will be entrained in the vapour stream and pass upwards into the baffle. A proportion of these small particles may pass through the baffle and into the condenser; this is known as carry-over. It will be obvious that for a given brine density in the evaporator the salinity of the made water (distillate) will be directly proportional to carry-over.

From the previous remarks it will be seen, therefore, that two main conditions must be fulfilled to obtain water of a given purity :—

(1) There must be a definite minimum height between the surface of the foam and the entrance to the baffle.

(2) The velocity of the vapour passing up the shell has a definite optimum value which must not be exceeded if carry-over of particles of the solid is to be prevented.

In general, if the height between the foam surface and the baffle is not adequate, sudden and irregular priming will occur, whereas if the vapour velocity becomes too great a definite and fixed increase in the salinity of the made water will result.

In the majority of cases these two parameters will be fixed in the design of the evaporator, and it is not always possible to undertake mechanical modifications of a plant to increase the height between foam surface and the inside of the baffle. It will be shown later, however, how this effect can be achieved by the use of a feed water additive. One particular example will be the effect of an anti-foam compound in reducing considerably the head of foam on the boiling brine and thereby increasing this height safety factor between brine level and the inside of the baffle. The net result will be to increase the heating surface immersed in the boiling brine and thereby to increase the output of distilled water from a given plant, whilst maintaining a high standard of purity.

Development of Feed Water Treatments for Preventing Scale Formation and Foaming

The feed water treatment in use by the Royal Navy during the last war was adapted from the Navy Boiler Compound/Starch Mixtures developed for the U.S. Navy by Rear-Admiral T. A. Solberg. This treatment was partly chemical and partly surface active in its action. The Navy Boiler Compound consisted of a mixture of sodium carbonate 40 per cent, di-sodium phosphate 47 per cent and corn starch 13 per cent. The complete treatment involved the addition of 10 oz of the above mixture, plus an additional 20 oz of corn starch, to 10 tons of sea-water feed.

Whilst undoubtedly this treatment when used correctly did to a degree reduce and control scale formation, the results obtained in general throughout H.M. Fleet were not satisfactory, hence the development of the present Admiralty Evaporator Compound. The earlier treatment did not give complete chemical control of scale-forming material, nor did the corn starch act as an efficient colloidal treatment for the modification of the physical character of the scale-forming solids. This was mainly due to practical difficulties in the mixing on board ship of the starch in boiling water to obtain a completely hydrolysed solution. Too often the starch was added in the form of a partially hydrolysed slurry which aggravated rather than eased the scaling problem. It is also obvious that to obtain adequate chemical control, stoichiometric proportions of feed water additives must be used. When the weight of scale forming matter passing into the evaporator is considered, it will be realised that stowage of the chemicals required is a major obstacle.

During the past ten years several successful feed water treatments have been developed, some for use over a wide range of operating conditions and for various designs of evaporating plant, and others specifically for a plant of particular design and set of operating conditions. Neither time nor space permit discussion of all these treatments, and it is the intention in the present article to describe only the treatment which has become the basis of the present Admiralty Evaporator Compound, now in use throughout H.M. Fleet and by many of the leading mercantile marine shipping companies.

It was decided at the commencement of this development that any successful treatment must conform to the following requirements :—

(1) The treatment must be effective in controlling calcium carbonate, magnesium hydroxide and calcium sulphate deposits.

(2) The quantities of feed water additive required must be small to reduce the weight and space for stowage of stock chemicals.

(3) The chemicals used must preferably be non-corrosive and essentially non-toxic in case carry-over should contaminate the distilled water.

(4) The chemicals used must be capable of easy mixing in cold or warm water.

(5) The treatment must be stable enough to permit a degree of under-dosing or over-dosing without any serious effect on the anti-scaling properties.

It has been found that the only treatment likely to fulfil these requirements is one involving the use of a powerful surface active material which, in low concentrations, will considerably modify the normal crystal habit of the scale-forming materials, thereby causing the scale to become non-adherent and friable, and to break away from the heating surfaces during operation. Belloid T.D., the sodium salt of di-naphthyl methane disulphonic acid, is the main scale preventative constituent used in the present treatment. This material is a very powerful anionic dispersing agent for calcium and magnesium compounds. It is non-corrosive and also non-toxic. The effective dosage of this material is only 0·002 per cent by weight on the sea-water feed, or about 6 oz per 10 tons.

During the evaporation of brine in the presence of Belloid T.D. this surface active material is adsorbed on to the surface of the precipitated crystal nuclei of the scale-forming material, thereby producing a particle with a pronounced negatively charged surface and at the same time considerably modifying the habit of the normal crystal growth. Similarly, the Belloid T.D. is adsorbed on the metal heating surface, giving it a negative charge. These small electrical surface charges on both scale particles and metal surfaces alike create a slight tendency for the particles to repel one another and to be repelled by the metal heating-surface, and thus account for the typical brittle and non-adherent properties of scale deposition in the presence of Belloid T.D. Natural flexing and movement of the heating coils during operation, due to pressure or temperature changes, results in the break-away of pieces of friable scale. Extensive areas of the heating coils are thus maintained clean to bare metal which ensures a marked improvement in the efficiency of the evaporator. This break-away of scale is continuous and all that has to be done is to ensure a regular daily blow-down of the evaporator and rake out the pieces of scale from the bottom of the shell. In addition to conditioning the scale within the evaporator the powerful dispersing action of the Belloid T.D. is notable for its effect in maintaining clean auxiliaries. Instead of brine pump impellers, brine strainers, &c., frequently scaling up, it is found that these also remain clean for lengthy periods.

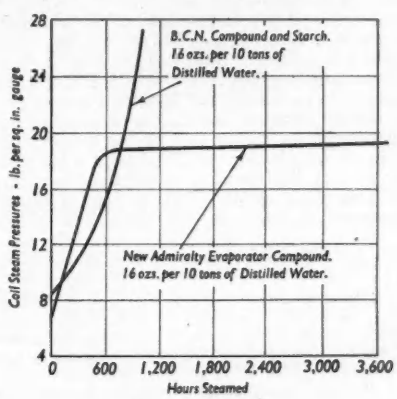
The second constituent of the Admiralty Evaporative Compound is the sodium salt of ethylenediamine tetra-acetic acid, a non-corrosive and non-toxic sequestering agent known by the trade name of "Sequestrol." The use of such chemicals in the field of water treatment is quite common. For instance, the complex phosphates, such as hexametaphosphate or tripolyphosphate are often used for complexing calcium or magnesium ions. In one particular application, the "threshold treatment," the addition of as low a proportion as 5 parts per million of sodium hexametaphosphate (Calgon) will hold in solution many times its own weight of calcium and magnesium ions.

However, in the evaporator system it is not possible to use the complex phosphates due to their decomposition and reversion to the basic di-sodium phosphates at the temperature of operation. Organic sequestering materials such as the above mentioned "Sequestrol," however, are stable in brine up to temperatures as high as 300 deg. Fah. The effective dosage is again 0·002 per cent by weight on the sea-water feed. In addition to the beneficial sequestration of a certain proportion of the calcium and magnesium present in the brine (thereby reducing the total weight of scale-forming material), the "Sequestrol" also takes up any free copper ions present in the brine that may have resulted from corrosion of the copper heating surface.

The presence of free copper ions in the brine has been found to have a profound effect on the degree of adherence of the scale to the metal surfaces. It has been observed that the initial scale layer appears to consist of a magnesium/copper complex, and this is true even if the bulk of the scale deposited later consists essentially of, say, calcium carbonate. It is the author's opinion that herein lies one of the reasons why the scale normally adheres so firmly to the metal surface, making it often necessary to use mechanical force to remove this initial scale layer. If this adherent bond between scale and metal could be broken it is obvious that scale would break away easily, and there would then be a possibility that this break away could occur during the normal operation of the evaporator due to the natural flexing of the heating coils.

The use of "Sequestrol," with its high efficiency for complexing metal ions, provides an ideal means of holding the copper in solution as a complex so that it is not available to combine with the magnesium. Examination of numerous scale deposits formed from brine treated with a mixture of Belloid T.D. and "Sequestrol" has shown that there is no adherent bond between the inner scale layer and the metal heating surface in such cases. Instead, the metal surface is bright and clean and the surface of the inner scale layer smooth and free from any traces of corrosion deposit, an ideal condition for the promotion of scale break away.

Typical operating results show that evaporators can now be steamed for 4000 hours and over without stoppage for coil removal and cleaning. Fig. 1 shows a typical result obtained



Operating Conditions

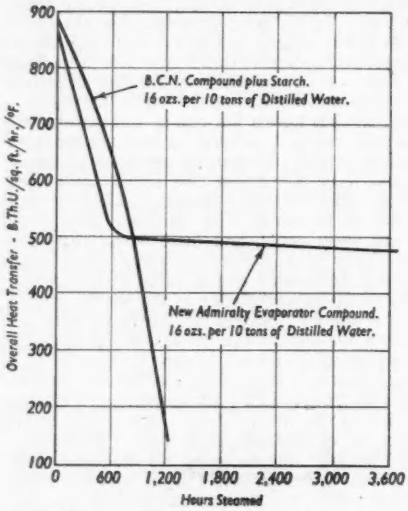
Evaporator capacity ...	5 tons per hour
Shell pressure	Constant at 20in vacuum
Brine density	Constant at 20 deg. Admiralty

Fig. 1—Typical operating results when using Admiralty Evaporator Compound

in the evaporators on board H.M.S. "Implacable." With this treatment the tendency is for the initial rate of scale formation to be about the same as without treatment, but after 500 hours' operation scale has commenced to break away freely, and from this point onwards a state of dynamic equilibrium is maintained where rate of formation of new scale equals rate of break away of old scale. Fig. 2 illustrates the same effect in terms of overall heat transfer against hours steamed, and emphasises the considerable gain in efficiency when using this treatment.

Finally I would refer to a third ingredient, a non-toxic anti-foaming compound developed for Admiralty by the Geigy Company, Ltd., which in the very near future will almost certainly be blended with the present Admiralty Evaporator Compound. The material is one of the polyethylene glycols which is capable of admixture with the previously mentioned chemicals to form a balanced anti-scaling/anti-foaming feed water treatment. This chemical has very powerful properties and is effective in quantities as low as 0·0005 per cent by weight on the sea-water feed.

As previously mentioned, an evaporator handling brine, either untreated or treated with the anti-scaling compound, may have a stable foam layer on the surface of the brine of at least 18in in depth. Due to the necessity of maintaining an adequate free volume between the surface of the brine/foam layer and the underside of the baffle to avoid entrainment and carry-over of salt droplets, it will be obvious that the surface of the foam cannot be allowed to rise much above the top of the heating coils. This in turn means that only about one-third to one-half of the heating coils are immersed in solid brine, the remainder being in a brine/vapour (foam) mixture. This foam will vary in density, and in the upper layer will be largely vapour. This means that the heat transfer from heating coil to brine becomes progressively lower as the vapour content of the foam increases, and in fact the top two or three coils are transferring very little heat at all. The use of an anti-foam additive will therefore allow the evaporator to work with all heating surface immersed in solid boiling brine, and should result in a considerable increase in output and operating economy for any given size of plant.



Operating Conditions

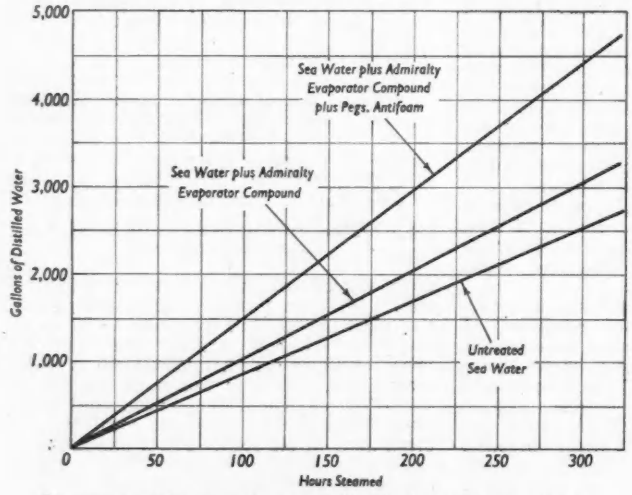
Evaporator capacity	...	5 tons per hour
Shell pressure	... ...	Constant at 20in vacuum
Brine density	... ...	Constant at 20 deg. Admiralty

Fig. 2—The effect of scale formation on overall heat transfer

Pilot plant evaporator experiments quickly proved the value of this suggested treatment, and Fig. 3 illustrates the increased output of pure water that can be obtained when using this particular compound ; an increase in output of some 50 per cent over that obtained without the anti-foam addition is recorded. One other valuable effect observed during this work was the apparent synergistic effect of the mixture of the polyethylene glycol and Admiralty Evaporator Compound on the anti-scaling properties of the mixture. The typical scale break away previously described was found to be taking place much earlier, and the state of dynamic equilibrium was reached at a lower coil steam pressure with a consequent increase in the operating economy. This we believe is due to the surface tension effect of the anti-foam influencing the size of the steam bubbles formed at the heating surface. Assuming the deposition of scale to commence at the interface of the steam bubble and heating surface, then rate and quantity of scale formed will be directly related to bubble size. When boiling sea-water without anti-foam addition the normal tendency is to form a large number of small steam bubbles, whereas in the presence of anti-foam the changed surface tension influences the formation of a reduced number of large bubbles. Hence, use of the anti-foam reduces the rate and quantity of scale deposited per unit area of heating surface.

Although full-scale proving trials of this anti-foam are still in progress, there has already been one very successful practical application of the new mixture ; this has been in the evaporators on board the Royal cruise liner S.S. " Gothic." Here, just prior to the ship leaving this country, a serious emergency had arisen concerning the performance of the ship's two 40 tons per day evaporators. On trial it had been found that these two plants (originally rated on fresh water), when evaporating salt water could not produce more than 10 tons per day each of pure water. Anything above this output caused heavy priming and salt contamination of the made water. During the period of the cruise it was necessary for the ship to produce fresh water from sea-water for a period of at least six weeks. The quantity required per day was some 40 tons of fresh water, so it is obvious why the original performance of the evaporators made the position so critical.

Mechanical modifications were immediately carried out under the direction of the Engineer-in-Chief of the Fleet's Department, being mainly an attempt to increase the height of the evaporator shell in an effort to reduce the carry-over of salt droplets into the baffle. This, as expected, produced an immediate improvement in the output of pure water, but it was still only possible to achieve an average output of 19 tons per day per evaporator, a total still slightly below the desired overall 40 tons per day, allowing no margin of safety for plant shut down or reduced output due to scale formation.



Evaporator maintained at maximum output throughout consistent with a distilled water purity of less than 0·02 grains CL per gallon.

(Pilot plant experiments)

Fig. 3—The effect of the " Pegs Antifoam " on distilled water output

In view of the remarkable success of the anti-foam trials, it was therefore decided to investigate the use of the new compound in these evaporators. The author spent two weeks on board the S.S. "Gothic" immediately prior to her departure, and a series of runs were carried out. The results achieved were outstanding and it was found possible to increase the average output to some 32 tons per day per evaporator. These trials continued for some 300 hours and at their conclusion the evaporators were opened up and examined. It was found with considerable satisfaction that up to 70 per cent of the heating surface was clean to bare metal and scale was cracking away freely from all areas. The condition of the coil surface was so good that cleaning was not necessary and the ship started her voyage without any further attention to either of the evaporators.

It is of interest to note the condition of these evaporators after several months' operation. A recent report from the chief engineer of S.S. " Gothic " (dispatched from New Zealand to her owners, the Shaw Savill Line) has fully confirmed the optimism in regard to this treatment. The ship had been steaming on one or other of the evaporators continuously since leaving this country, and she was still getting enough fresh water from one evaporator to satisfy the needs of the ship's complement.

Results Achieved by the New Feed Water Treatment

The results of scientific achievement are not always easy to assess in terms of direct financial savings. However, in the case of the production of fresh water from sea-water, a product is obtained which can be costed in terms of fuel oil burned to provide the primary heating steam for the evaporators. It is interesting, therefore, to balance expenditure on scientific effort against anticipated savings in the cost of fresh water resulting from the improved efficiency of the evaporating plant.

In the majority of existing modern design evaporating plant the output with clean heating surfaces is sufficient to cover the ship's normal fresh water requirements. Scale formation, however, rapidly reduces the distilled water output and the plant has then to be forced in order to maintain water production. This results in a lowered operating efficiency and wastage of heat. Development of the latest anti-scaling/anti-foaming evaporator compound has increased the operating life of the evaporator fivefold and coil cleaning and changing has been eliminated during this period. As the continual break-away of scale leaves a high proportion of the heating surfaces clean to bare metal, the average overall efficiency has been increased by some 30 per cent over that achieved when using the previous B.C.N./starch compound. On this basis the following savings emerge :—

Cost of water produced, 18s. per ton prior to the present treatment, 12s. per ton with the new feed treatment.

Saving in fuel oil burned at the boilers, 34 tons of fuel oil per 1000 tons of made water.

To be offset against the above savings will be the increased cost of the feed water treatment at about 4d. per ton of made water.

Now, assuming a total production of water throughout the fleet of 2,000,000 tons of distilled water per annum, the cost of producing this prior to the present feed water treatment would be roughly £1,750,000 (inclusive of the cost of the old feed water treatment at 0·2d. per ton of made water). The cost of production with the present feed water treatment would be about £1,250,000 (inclusive of the cost of the present treatment at 4d. per ton of made water). A net saving of some £500,000 per annum is thus obtained.

The total cost of the research work over the past nine years (which has resulted in the development of this latest compound) amounts to £10,000 for salaries and, say, £5000 spent on equipment, supplies of chemicals, &c. This represents a total of £15,000 to be offset against the estimated annual saving of £500,000.

Future Design Distilling Plants

Apart from the established advantages of the new methods of feed water treatment, steps are being taken to reduce the inherent inefficiency of the sea-water distilling plant.

In a previous article in this journal the author described the vapour compression distillation plant and outlined the economics of this system of evaporation. It is sufficient here to stress the importance of this method of distillation and to emphasise the considerable reduction in the cost of fresh water produced. Extensive development programmes are in progress aimed at the use of these evaporators not only on board ship, but also for land applications.

In particular, the electrical and diesel-driven vapour compression evaporator is likely to be of considerable value in any future ships that may be dependent on sources of propulsive power other than conventional steam-driven turbine machinery. Cost estimates have shown that with a diesel-engine-driven vapour compression plant, fresh water can be produced for as low as 3s. to 4s. per ton, a big saving compared with the present best figure of 12s. per ton. It should

be noted that this type of evaporator still suffers from the inherent difficulty of scale formation on the heating surfaces and present experimental work is directed towards the development of specific treatments for this design of evaporator.

The impact of this anti-scaling/anti-foaming compound on evaporator design may be considerable. In the past, evaporator designers and manufacturers have accepted the heavy penalty of loss in efficiency due to scale formation. When designing a plant for a given rated output they have had to allow for low heat transfer values by providing a large heating surface area to enable the plant to produce its rated output with scaled surfaces. Similarly, with the effect of foaming, shell heights have been designed to afford an adequate margin of safety so as to prevent entrainment and carry over of salt droplets. With the new conception of cleaner and fully immersed heating surfaces without foam formation, it will now be possible to streamline the design of evaporating plant considerably. Coil areas for a given output of made water will be less and the free volume of the evaporator shell can be reduced if there is no danger of heavy foaming and carry over. This will result in the design and manufacture of smaller and lighter evaporator equipment with associated benefits to the layout of the engine-room machinery.

It is also essential to use as much low-pressure steam as possible (from which energy has already been extracted in the turbine) for evaporator heating, as this provides a large source of low-grade heat which is virtually cost free. Future conventional evaporator design is swinging rapidly towards this goal, but to achieve success the evaporator must operate with a lower temperature differential between heating steam and brine boiling temperature. Here, again, scale formation is a matter of major concern, and for the successful operation heating surfaces must remain as free from adherent scale as possible.

Alternative Methods of Sea-Water Purification

It will be obvious that any method of fresh water production involving the evaporation of the sea-water will always be subject to scale formation on the heating surfaces, and will require the application of feed water treatments to minimise or prevent this scaling.

Whereas ion exchange processes are an economic and very satisfactory method for the desalting of low salinity waters (up to, say, 2000 parts per million chlorine) they do not offer a practical economic process for the desalting of sea-water (30,000 parts per million chlorine). The main reason lies, of course, on the one hand, in the very short operating life of the resin bed before regeneration would be required, and, on the other hand, in the excessive quantity and cost of the regenerative chemicals required. There are, however, two alternative methods, based wholly or partly on ion exchange principles, which are at present under active consideration.

The first of these is based on a possible use of one of the new ion selective resins for the partial desalting of the sea-water, followed by a conventional evaporation process. The High Polymer Group at the Chemical Research Laboratory, Teddington, has recently formulated an ion exchange resin with the ethylenediamine tetra-acetic acid radical as the active group (our previously mentioned "Sequestrol" addition in Admiralty Evaporator Compound). This resin has been found capable of adsorbing calcium and magnesium ions selectively in the presence of large quantities of the sodium ion (a feature that is lacking in the conventional ion exchange resin, and one that makes its use in sea-water an impossibility due to the preponderance of sodium ions). The resin, once saturated with calcium and magnesium, would then be regenerated with the concentrated brine effluent from the evaporator. The proposed technique would be to remove sufficient of the calcium and magnesium from sea-water to prevent further deposition when the water is concentrated in the evaporator, thereby eliminating a considerable proportion of the scale deposited.

The second method is that of electrodialysis, where a plastic membrane impregnated with an ion exchange resin is used as an ionic sieve. A complete electrodialysis unit consists of a series of cells in which are placed a large number of closely spaced membranes having alternate anionic and cationic properties. Each cell is provided with a suitable anode and cathode across which the required e.m.f. is maintained. Sea-water entering the cell flows between the membranes, the anions passing through the anion permeable membrane, the cations through the cation permeable membrane, and the desalted water passing up through the centre of the membrane. The caustic catholyte and acid anolyte streams are passed to waste.

Whilst large-scale units are on the verge of development for desalting low salinity waters at a very low cost per ton of desalted water, their application to the desalting of sea-water is still in the research stage. It is the author's opinion that such units will be developed for land use and should be capable of producing fresh water for as low as 4s. to 5s. per ton. However, for naval application there does not appear to be much promise that they will replace the large steam heated or vapour compression evaporator. This is mainly due to the space occupied by, say, a 50 tons per day unit compared with one of the conventional evaporators, and also the high power consumption when desalting water of 30,000 parts per million chlorine down to 5 parts per million chlorine. There is, however, one exception to this statement, this being the possible development of an electrodialysis unit for submarines, and this field is under active investigation. Here the provision of a unit completely silent in operation, and occupying about the same space as the present vapour compression plant, is the important factor.

One final application of the technique of electrodialysis is the possibility of forming permeable membranes in which is incorporated one of the selective ion exchange resins such as is based on ethylenediamine tetra-acetic acid. This application is under investigation at present and, if successful, the use of an electrodialysis cell for the partial removal of calcium and magnesium ions from the sea-water prior to further evaporation will be investigated. The advantage of this system over the use of the straight complexing resin bed is that it would provide a once-through system and regeneration would not be required.

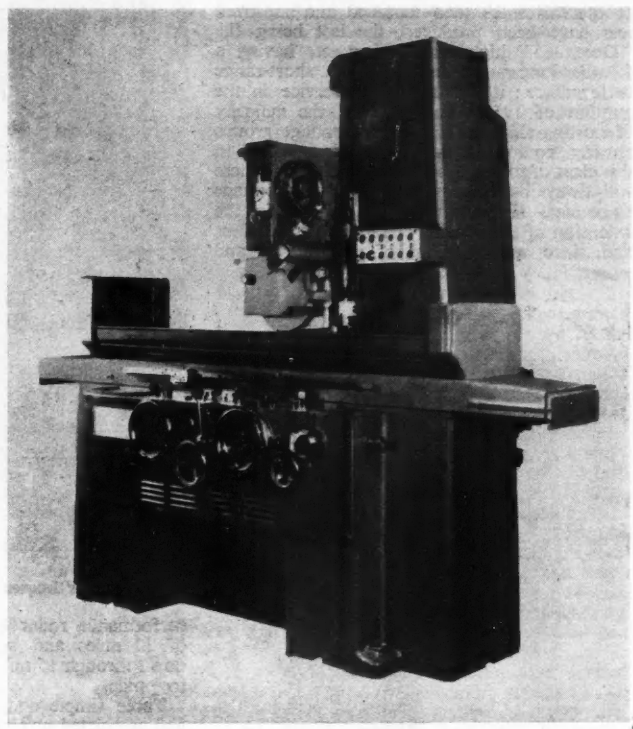
It has been reported that throughout a total of 1900 hours' service the evaporators of S.S. "Gothic" have worked perfectly and are now producing 28 tons per day from each evaporator.

Automatic Surface Grinding Machine

Particulars of a new surface grinding machine made by the Swedish firm A. B. Malcus Holmquist, have been received from its agent in this country, the Selson Machine Tool Company, Ltd., Chase Road, London, N.W.10. This machine is available with two sizes of table, one with a working surface 40in long by 12in wide, and the other 59in long by 12in wide. It is designed for automatic cycle operation and its various motions are hydraulically actuated.

The table speed of the machine is steplessly variable up to 100ft per minute, and the handwheel is automatically engaged and disengaged when the hydraulic motion is stopped and started. Automatic hydraulic cross feed of the grinding wheel at each table reversal can be varied in increments from 0·02in to 2in. Means of rapid wheel cross traverse are provided, and, if required a profiled template can be fitted to operate this rapid traverse intermittently to save time when grinding work with several large surfaces spaced some distance apart.

The grinding wheel spindle takes wheels up to 12in diameter by 2in wide, is driven by vee belts from a 5 h.p. motor at 2065 r.p.m. When using a new wheel work up to 15¾in high can be accommodated on the table. The wheel head assembly is moved up and down on the column by hydraulic means or by a handwheel. Automatic hydraulic down feed, variable from 0·00008in to 0·002in, can be set to operate at each reversal of the table, or at the end of the cross feed motion. A micro-feed device, which is automatically engaged just before a workpiece is ground down to the final dimension, feeds the final passes at from 0·00008in to 0·0004in per reversal. The engagement of this finishing feed is shown by an indicator lamp, and when the pre-set dimension is reached the down feed is automatically disengaged, table feed is stopped and the rapid travel motion engaged to raise the wheel.



Surface grinding machine with hydraulically operated, steplessly variable automatic feeds to all motions

A hydraulically operated diamond wheel truing device is fitted, and to compensate for truing losses on the wheel the dial gauge used for down feed adjustment is moved up automatically by increments corresponding to the reduction of wheel radius. To supplement the handwheel-operated down feed a push button down feed motion is fitted and it lowers the wheel in increments of 0·00004in.

The pump fitted to the hydraulic system is designed to adjust its capacity automatically in accordance with the load and all the hydraulic controls are grouped on the base for convenient operation. This pump, with its motor and tank, is mounted on a vibration-damping suspension in the base of the machine. The electrical controls, relays and fuses are grouped in a terminal box in the machine base, and the buttons of the electrical controls are mounted on a panel at the front of the machine.

Synthetic Chip for Barrel Finishing.—A new fast-cutting chip for barrel finishing is now being supplied by Roto-Finish, Ltd., 39, Park Street, London, W.1, under the trade name "Coruloy-T." The chips are made of a fine grain, tough synthetic material.

Simplified Marine Radar Set for Small Ships

WARTIME developments in radar have since been applied in many directions, particularly in the marine field, as a navigational aid to ships. It was in 1949 that Decca Radar, Ltd., exhibited its first set and at intervals since then modified and improved sets have been produced, the last being the "Decca 45" high performance set, having a 45-mile long-range and a ¼-mile short-range performance; it was ready for service in the autumn of 1953. To-day, with the majority of existing ships in the larger tonnage groups already equipped, the potential market in this class of tonnage is shrinking, although there will always be the requirements of new tonnage to be met. However, there is a demand for the extension of the benefits of radar to small ships and, since considerations of weight, size and price made existing models unsuitable, the Decca company has designed new equipment for this market.

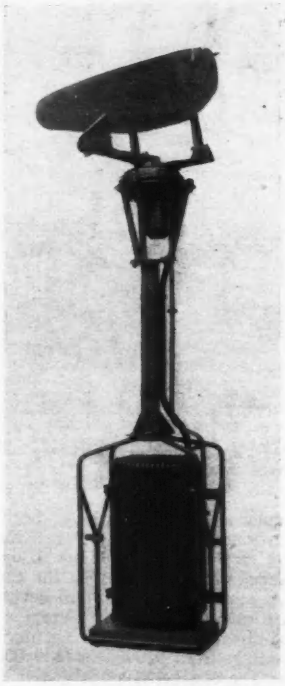


Fig. 1—Scanner combined with radar frequency unit in waterproof housing

The new model is the "Decca 212," which recently we had the opportunity of observing under operational conditions during a short voyage on the Thames on board the company's M.Y. "Navigator."

Before settling details of design of the new set, due regard had to be paid to certain fundamental considerations. First, tooling and assembly costs had to be kept low to ensure the production of a set of low price. This requirement set a problem in that operating conditions in small ships called for an especially robust set while navigation in coastal waters indicated the need for a set having a high standard of performance. The apparently conflicting demands of low price and high performance have been achieved, it is claimed, in the new set by simplification of both mechanical and electrical design without sacrificing any of its essentials. The simplicity attained will have the secondary but important effect of improved operational reliability. The "Decca 212" set is a full performance radar having a maximum range of 30 miles and six range scales extending down through 15 miles, 8 miles, 3 miles, 1 mile, to ¼ mile.

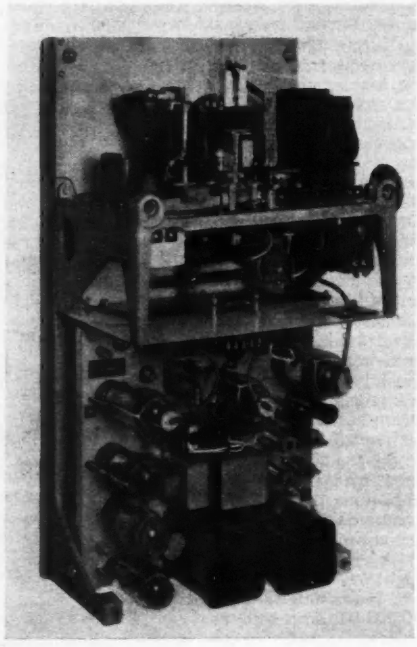


Fig 2—Radar frequency unit with cover removed

Three simple units (consisting of a scanner and associated turning motor, a radar frequency unit including a magnetron, klystron and mixer, and a display unit with a 9in fixed focus cathode-ray tube) form the set, while in addition there is a motor alternator for conversion from the ship's to a special radar supply. The scanner unit, weighing about 75 lb and capable of operating in winds of up to 75 knots velocity, consists of a single tilted parabolic cylinder reflector, driven at 24 r.p.m., which produces a narrow horizontal beam of 1·75 deg., for high picture quality, and a vertical beam of 20 deg. at half-power points, with a low side lobe level for good performance in narrow waters. The side lobes are stated to be better than 22 db within ±10 deg. of the main beam and better than 30 db outside ±10 deg. A peak power output of about 10kW is given by the radar frequency unit with dual pulsing, of 0·2 or 0·1 microseconds duration, and a recurrence frequency of 1000 per second, for solid points at long range and sharp pictures at short range. The unit is designed for mounting below deck or above deck in a special waterproof housing. This external fitting is shown, together with a scanner, in Fig. 1, and another illustration (Fig. 2) shows the details of the layout of the radar frequency unit.

It has been mentioned already that the display unit, which is of rugged splash-proof design and built around a 9in fixed focus tube, with long afterglow screen, has six range scales extending from 30 miles down to ¼ mile. The unit has an edge illuminated bearing scale calibrated in degrees, a manually rotated cursor, also edge illuminated, and a minimum range of about 30 yards. Well-grouped controls are fitted and they have distinctive shapes to facilitate identification on the darkened bridge. The display unit which weighs 59 lb is designed for easy mounting in four different positions, namely, deckhead, chart table, on a deck pedestal, or bulkhead, as shown in Fig. 3. The other photographs (Figs. 4 and 5) show the radar picture with the set operating on 0·2 microseconds pulse at 30 miles range, and on 0·1 microseconds pulse on the ¼ mile range scale. The power unit for the conversion from the ship's supply voltage to the special radar voltage has a weight of 137 lb. The "Decca 212" has completed practical tests at sea and the design meets the requirements of the Ministry of Transport Marine Radar Specification.

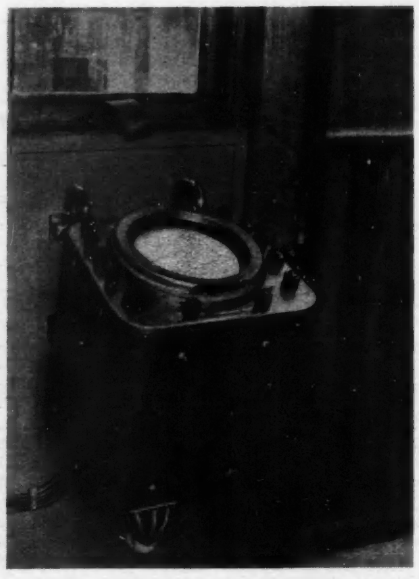


Fig. 3—Display unit mounted on bulkhead

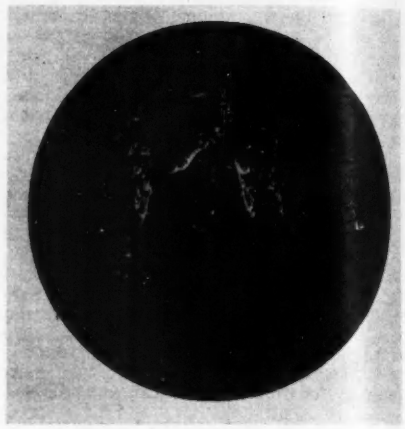


Fig. 4—Radar picture on 30-mile range scale

Fig. 5—Radar picture on ¼-mile range scale

Conference on the Automatic Factory

A PRESS conference was held at the Institution of Production Engineers last week in connection with the conference on "The Automatic Factory—What Does it Mean?" which has been organised by the Institution and will be held at Margate from June 16th to 18th next.

In addressing the meeting, Major-General K. C. Appleyard, the chairman of the conference organising committee, said that much had been written about the so-called automatic factory, which did not exist in the form that most people imagined, and from its birthplace, the United States, the word "automation" was now becoming widely known in this country. The word represented nothing fundamentally new and industrially the development of automatic production had been going on ever since machinery was first used. Its objectives had always been the same: first, to increase the mechanical power at the disposal of the worker and assist him to increase his output, and, secondly, to eliminate drudgery and monotony from work. What had been happening was that scientists and engineers had been placing new kinds of apparatus at the disposal of production workers which enabled manufacturing processes to be carried out in new ways, and so enable productivity to be increased, costs to be kept within reasonable limits, goods to be made more readily available to the mass of population and competitive trading to be maintained in overseas markets.

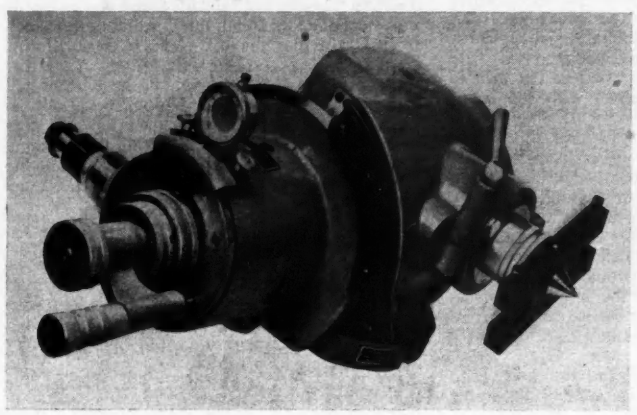
Major-General Appleyard went on to say that the object of the conference to be held at Margate was to provide the members of the Institution with an opportunity to get together and, with the stimulus of a series of papers by authorities on the subject, to examine the progress which had been made to date in automatic production.

Sir Walter Puckey, the President of the Institution, then pointed out that during the last few months capital expenditure schemes totalling many hundreds of millions of pounds had been commenced, and it was inevitable that many new factories would be concerned with new developments, new techniques and new equipment which would bring about advances towards the automatic factory. The rate of change in industry was likely to increase in the future and it was now a particularly significant time to review the technological trends and to decide whether objectives were clear or whether in the solution of some problems others were likely to be raised. One very important problem was the effect on people of the automatic utilisation of machines, and the Institution hoped to show clearly an increase in automatic production, far from displacing people, would give greater opportunities for all.

The plenary session of the conference will be opened with addresses by Sir Walter Puckey on "Automatic Factory—Dream or Nightmare"; The Earl of Halsbury on "Technical and Human Problems for the Automatic Factory," and Mr. F. G. Woollard on "Machines in the Service of Man." At each of the discussion sessions five papers will be presented, and these papers will be as follows: "Computers—Electronics Contribution to Production," by Mr. C. Metcalfe; "Automatic Control in the Petroleum Industry—A Case Study," by Mr. I. McCallum; "Prerequisites of the Automatic Chemical Factory," by Mr. A. J. Young; "The Automatic Mechanical Project Factory—A Sight of Things to Come," by Mr. H. J. Graves; "Automatic Transfer Machines," by Mr. P. Bezier; "The Automatic Office—Industry's Electronic Pulse," by Mr. D. W. Hooper; "Instrumentation—A Key to Automation," by Mr. A. G. Peacock; "Automatic Inspection—The Anatomy of Conscious Machines," by Mr. J. A. Sargrove; "Automatic Linking Devices," by Mr. J. A. Hunt; "Computer-Controlled Machine Tools," by Mr. D. T. N. Williamson; "Materials Handling—Automatic Selection, Weighing and Conveying"; "Automation—Some Problems of the Boardroom," by Mr. M. Seaman; "Automation—Some Problems for the Manager," by Mr. F. Garner; "The Engineer and the Automatic Factory—A Challenge to the University," by Professor T. U. Matthew; "The Engineer and the Automatic Factory—A Challenge to the Technical College," by Mr. C. L. Old; "The Automatic Factory: The Age of Harmony, Leisure and Plenty?" by Professor B. R. Williams, and "How Will Trade Unions React to Automation," by Mr. E. Fletcher.

Universal Dividing Head

THE accompanying illustration shows a universal dividing head which is being manufactured by Hommelwerke G.m.b.H., (17a) Mannheim-Kaefertal, German Federal Republic. This model differs from the standard pattern chiefly in that instead of using a large number of index plates it has only one. Each of the six divisions of that plate corresponds to 1 deg. of rotation of the work spindle, sub-divisions and multiples being derived from the readings of a dial gauge which is actuated by a cam connected to the index plate. The index plate is clamped to the housing and the index arm to the spindle, by means of the knurled nuts shown in the illustration; the third nut engages and disengages the drive from the change gears. In order to obtain any angle required, the index arm is rotated from zero through the necessary number of full turns to the corresponding reading of the dial gauge. The index plate is then clamped to mark this position. A bracket overhanging the index plate is then fitted by means of the two knurled nuts seen on either side of the dial gauge. The hole in this bracket serves as a zero for the index pin. By setting the index arm back to this hole while the work spindle is clamped, and then rotating the arm until the pin can be dropped into the marked position on the plate, the angle may be repeated. The work spindle of this dividing head can be set at any angle between horizontal and vertical to within ±5 minutes of arc by means of a Vernier. In another version, which is also manufactured, the change gear drive is omitted, but provision is made for incorporating it later when required. The agent in this country is Catmur, Ltd., 103, Lancaster Road, London, W.2.



Each of the six divisions of this single-plate universal dividing head corresponds to 1 deg. of rotation of the work. All other angles may be derived from the reading of the cam-operated dial gauge

Precision Measuring Room

FOR many years, Alfred Herbert, Ltd., has maintained an extensively equipped measuring room at its Coventry works, both for its own use as an A.I.D. gauge test house, and for the demonstration of precision measuring techniques. Recently, in order to provide more adequate and better accommodation for the extended range of precision measuring equipment now available, this department was transferred to larger and more modern premises. In the new department, which is shown in the accompanying illustration, the equipment is well spaced for effective use and demonstration, with the larger machines arranged along the walls and the smaller equipment situated on benches down the middle of the floor. Adequate service points are provided along the walls and down the centre between the benches for the introduction of new measuring tools and apparatus as they are introduced.

The equipment installed includes that of several makers of precision measuring apparatus for whom Alfred Herbert, Ltd., acts as distributors. Amongst the equipment are various designs of projectors, multi-dimensional inspection machines, comparators, precision levels, protractors, micrometers; a hardness testing machine, a dynamic balancing machine, an engineer's microscope, an optical dividing head, a circular division tester, a hob flank tester, a cutting tool dynamometer, an alignment tester.

With this new measuring and inspection department it is now possible both to use the equipment for investigating problems and to show the way in which modern precision measuring apparatus can be used to ensure quality control, speed inspection, and reduce its costs and increase efficiency, on the production lines.

New measuring room at the works of Alfred Herbert, Ltd.

The Civil Engineer and Britain's Atomic Factories

By D. R. R. DICK, M.I.C.E.*

We reproduce here abstracts from a paper with the above title which was presented at the Institution of Civil Engineers on Tuesday, March 8th. Many of the structures described in the paper are on a massive scale, and are built to a very high degree of accuracy. Research and development work is going on continuously, and changes resulting from new information must be allowed for at all stages of construction.

EARLY in 1946 the Ministry of Supply, in association with the Ministry of Works, was instructed to proceed with the design and construction of research and production establishments for the development of atomic research and the production of fissile material. Since that time, considerable experience has been gained in the problems peculiar to such work. Many of the problems are associated with the fact that the substances handled in the atomic establishments are radioactive, with the result that the structures must have the additional function of acting as containers of this radioactivity. Other problems arise from the fact that research and development work is going on continuously, and its impact is felt on work under construction to an unusual extent, in that it is the exception rather than the rule that a pilot plant should be built before the production plant. Finally, there are problems which arise from the massive scale of the individual structures, particularly where the work is to be carried out to an accuracy not normally associated with civil engineering.

It will always be the aim of the designer to reduce the gap between knowledge becoming available from research and its application in practice. For this to be feasible during construction, without prejudice to the target completion dates for each building, it is essential that the design of the structure shall afford the plant designer maximum freedom. It is here that the structural engineer has a major contribution to make. It was said by Sir Christopher Hinton, in his James Clayton Lecture† to the Institution of Mechanical Engineers, that it is important to be successful rather than clever in this kind of work. Experience has shown that designs that exactly fit the requirements known at the time are rarely successful owing to lack of flexibility. Since each plant is normally the first of its kind, it must be expected that minor adjustments will be required during the trial runs, and provision must, therefore, be made in the structural design for such adjustments to be made without any corresponding adjustment to the target completion date.

Operation of the Plant

All nuclear reactors and most chemical plants are walled up within a shield of brick or concrete, and are designed on the assumption that it will not be possible to carry out any maintenance once the plant has been operated under radioactive conditions. Provision is normally made for access, but this could only be used after an extended shut-down, and then only for short periods.

In a typical chemical plant, the process plant is housed within the concrete box ; in one case nearly 200ft high. The box, in turn, is surrounded by a steel-framed building supporting chequer-plate floors on which the control stations and inactive plant are located.

The control of the operation of the plant is, therefore, maintained from outside the shielding box, and all pipework, shafts to rotating machinery within the box, charging and discharging arrangements have to pass through the shield.

Nuclear Reactors

Since 1946 four self-sustaining nuclear reactors have been completed in Great Britain. All four reactors are graphite moderated with natural uranium as the fuel. Basically, each reactor consists of a large mass of graphite built up of individual blocks, in which there are horizontal channels containing the uranium cartridges. The individual graphite blocks of the B.E.P.O. are 7¼in square by 29in long, and are machined to a tolerance of ±0·0025in. By careful selection of over and under-sized blocks it was possible to achieve an accuracy at every level of ±0·015in. This mass of graphite, containing 1760 horizontal channels, rests on a 6in steel base made up of individual plates carefully levelled to the same degree of accuracy. The removal of heat from the reactor is effected by an induced draught system of air cooling ; the inlet and outlet headers are bridged by tubes opposite each channel in the graphite, through which the uranium cartridges travel during charging and discharging of the reactor core. Surrounding the reactor is a concrete " biological snield," faced on the inside with steel plate up to 6in thick, which is described as the " thermal shield." The purpose of this thermal shield is to absorb the energy of thermal neutrons, thus cutting down the heat generated in the concrete forming the biological shield.

Because the uranium cartridges have to pass through the biological shield during the charging and discharging operation, the shield of concrete is honeycombed with tubes opposite each channel in the graphite ; these tubes must register accurately with the corresponding channels in the graphite. The other two walls of the shield are also perforated by tubes—though to a lesser extent—for control gear and experimental facilities. The main problems associated with the concrete walls of the biological shield are :

(1) The achievement of a uniform high density in the concrete as placed.

(2) The setting of all tubes, &c., through the shield walls to the required degree of accuracy.

These problems are not restricted to the walls ; they apply equally to the roof and are enhanced by problems of deflection and high stresses resulting from the roof being self-supporting over the top of the reactor.

The Windscale reactors are very similar to B.E.P.O., except for their size and the fact that they are designed for continuous operation rather than as experimental tools. The scale of the Windscale reactors may be illustrated from the fact that the load imposed on the ground by the concrete raft is 58,000 tons, and that the top of the biological shield is more than 80ft above ground level. It cannot be overemphasised that the scale of these reactors made the achievement of uniform high density in the concrete, and accuracy in the setting out of the tubes, very much more difficult.

Accuracy in Reactor Structures

It will be appreciated that the achievement of great accuracy in very large structures is not easy in conditions where the datum points may be up to 60ft away from the point at which the work is being carried out. Particularly is this so where the intervening 60ft is a maze of scaffolding and contractors' plant. The principles followed in achieving such accuracy have, therefore, been :

(1) All datum points should be carried up as the work proceeds.

(2) Accuracy, once achieved, must be maintained without the use of optical instruments.

(3) As much of the accurate work as possible should be carried out in workshops, since time spent in levelling and positioning necessarily interferes with the smooth running of the concreting programme.

The G.L.E.E.P. at Harwell is by far the simplest of the reactors mentioned, but it was also the first to be completed. The internal dimensions of the biological shield are approximately 25ft cube, and were to be maintained at all levels within ±½in. The graphite was supported on a steel baseplate, made up of individual plates which were to be set to ±0·015in. The strength of graphite in tension is not great, so it is important that there should be no measurable difference in levels between individual baseplates, because the junction between plates is straddled by the graphite blocks.

Before deciding on a steel baseplate for G.L.E.E.P. an experiment was tried of laying a terrazzo screed and grinding it off to the tolerance specified. It was found impossible to obtain a closer tolerance than ±0·025in, and it was considered that even this represented a very great achievement by the plasterer carrying out the work.

The baseplate for the G.L.E.E.P. consisted of individual plates 4ft by 3ft, resting on a grillage of 20in by 6½in R.S.J.s, the top flanges of which had been planed. The joists were levelled from a concrete foundation and then grouted in position. Differences in thickness of baseplates were overcome by machining the underside of the plates where they took a bearing on the joists. No difficulty was experienced in obtaining the tolerances specified of ±0·015in.

A similar system was used for B.E.P.O., but the grillage joists were only 8in by 6in R.S.J.s and considerable difficulty was experienced in achieving the tolerances owing to the distortion of the joists during levelling operations.

At Windscale, the baseplate was stepped and, therefore, presented slightly different problems. In addition, thermal insulation and a cooling air passage had to be provided on the underside. Once again, the main grillage consisted of 20in by 6½in R.S.J.s, but each plate was levelled by means of screws at the corners, which, in turn, rested on hard packings welded to the joists. This method of levelling was so successful that it is now adopted in all such cases.

A steel framework was housed within the concrete forming the biological shield for the G.L.E.E.P., which acted as the permanent jig for the work. There is no doubt that such a jig would now be regarded as unnecessary for a reactor as simple as the G.L.E.E.P. Since it was constructed, however, a large number of structures have been erected to similar or closer tolerances, and the experience gained on this framework has enabled work of a similar kind to be carried out by steelwork erectors without any serious difficulty. In the case of the G.L.E.E.P. errors were allowed to creep in during the erection and, owing to the interdependence of the structure, they could not be eliminated until the framework had been partially dismantled. Once these erection errors had been eliminated the framework proved entirely satisfactory for its purpose.

In the case of B.E.P.O. a permanent jig housed within the concrete shield was also used, but it was much more elaborate owing to the greater complexity of the reactor. The main stanchions carry the thermal shield plates on the reactor side and, on the outside, steel shutter plates are fixed to which experimental and other equipment was later attached. The stanchions are interconnected by steel lattices of diamond shape and where tubes pass through each lattice they are held in position by four set-screws, by which accurate alignment of the tubes was achieved. The fabrication of this framework, which was all-welded, called for careful jigging and a welding procedure that would avoid distortion of the members. Accurate fabrication was successfully achieved and the framework, when erected, formed an excellent jig. The design, however, meant that 1760 tubes in each of two faces had to be carefully levelled and aligned with the corresponding tubes in the opposite face, and the presence of the framework made the placing of concrete a very difficult process. The procedure was to align and concrete each layer of tubes one by one, which involved the intermingling of the engineering and building trades at all levels.

When the Windscale reactors came to be designed it was felt that these features should be eliminated if at all possible. Only one wall of the biological shield was to be heavily honeycombed with tubes, and it was decided to group the tubes in units incorporating two layers of tubes. Each unit consisted of two steel shutter plates, approximately 20ft long by 3ft high, between which the tubes were fixed. These " cages " were hoisted into position by crane and accurately levelled up from the " cages " below them. The required accuracy was easily obtained, but it was found in practice that it was extremely difficult to work the concrete through the two layers of tubes and to achieve a uniform high density.

The other walls of the shield were also perforated by tubes and other apertures, but it was

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† This lecture was reproduced in THE ENGINEER of March 5 and 12, 1954. Our articles included several illustrations of the construction of the reactors described in this abstract.

decided to provide these with individual steel supports bearing on the lift of concrete completed immediately below them. Great care was taken to ensure that their form was such that air would not be trapped during concreting.

These measures had the desired effect of reducing interference with the concreting programme to the minimum, and access to the areas being concreted was much improved. The lack of any form of jig, by which levels and positions could be readily checked, meant that heavy demands were made on the time of the engineering staff. This position was aggravated by the fact that adjoining walls were often as much as 20ft out of step, in that no concreting could be carried out on any one wall while tubes were being accurately positioned, and the adjoining wall would thereby gain a lead. It was not surprising, therefore, to find that the tolerances on the concrete work were not always achieved. Owing to the large number of fixings for the thermal shield guides, &c., that were cast into the concrete, any adjustment afterwards was extremely difficult, since these fixings, which consisted of fabricated bolt housings, determined the face of the concrete.

In addition to the reactors already completed, work is now proceeding on the two reactors for power production at Calder works. The biological shield around these reactors is octagonal in shape, and a structural steel spider has been provided in the well of the octagon in place of normal scaffolding. This spider, which is removed after the concrete work is complete, constitutes a jig to which the work is set, and from which the accuracy of the work can be checked continuously, as well as providing the scaffold by which access is gained to the work.

Future reactors will have to be treated on their merits, but the principles governing the introduction of the steel spider are likely to apply. It constitutes the most satisfactory and economic solution yet found to one of the major problems of the structural engineer in reactor construction. For several years the trend in reactor design has been towards the location of all control, charging, and discharging gear on the top face of the reactor. The effect of this is to reduce the number of tubes, &c., penetrating the walls and thus simplifying their construction. As a corollary to this, the concrete roof over the reactor has tended to become more and more complicated.

Biological Shield Roof Over Reactors

In the biological shield roof over B.E.P.O., as in G.L.E.E.P., steel beams are housed within the thickness of the roof and span on to the steel framework within the walls. To these steel beams were fixed shutter plates which, in the case of B.E.P.O., were permanently installed, since the thermal shield plates were used for the purpose. Any further complication in the roof design involving additional ducts, tubes, &c., would render the presence of such beams within the concrete thickness a severe embarrassment, if not an impossibility.

The biological shield roof over the Windscale reactors spans more than 50ft in each direction and is 8ft 6in thick. On its underside is suspended 6in steel plating as a thermal shield, which is free to move under thermal expansion. Any strutting of the underside would have been difficult, but it was in any case unacceptable, because it would have held up work in the reactor vault itself. Whereas it would have been possible to suspend the shuttering from steel plate girders housed within the thickness of the roof, it was felt that this might have an adverse effect on the shielding properties of the concrete roof. In addition, the roof would inevitably span in two directions, and the introduction of reinforcement at right angles to the plate girders was obviously going to be difficult.

It was, therefore, decided that the shuttering to the roof should be suspended from a system of supports located above roof level. Such supports would only be temporary, and Bailey bridge girders were selected because of their high recovery value. A series of double-double girders span between the biological shield walls, where they bear on timber spreaders. Below the girders are suspended intermediate lines of 6in by 3in R.S. channels, which pick up the hanger rods.

More Normal Structures

Emphasis has been placed on the special requirements imposed on the structural designs by the nature of the plants and the materials handled in those plants. The problems associated with those requirements have always tended to loom so large that they have dwarfed those which the civil and structural engineer must expect to meet in factories of this scale ; that is, in factories where buildings between 100ft and 200ft high, foundation rafts to carry 25,000 tons, reinforced concrete chimneys 200ft to 300ft high, bridges over railways, roads and rivers, and any number of steel-framed shed buildings tend to be regarded as relatively common place and straightforward.

It would perhaps be wrong to omit mention of at least one of these more normal structures, in particular the steel-framed buildings housing the reactors at Windscale works.

The framework for these buildings is to a portal frame design, the height to eaves being 140ft and the plan dimensions 200ft by 90ft. The frames are propped by horizontal wind girders at roof level carried back to a vertical bracing system in the gables ; this system is so designed as to restrict the horizontal movement of any point in the structure to 4½in under gale conditions. These buildings were designed for two conditions—first, the building acted as a cover over the reactor during its construction, and, secondly, the centre bays of the steel frame were cast solidly into the biological shield at a height of 80ft, thereby reducing to 1½in the deflection at any point. This restriction on deflection was of great importance, since the frame carried a crane of 25-ton capacity which is used to lift equipment associated with the reactor, much of which needs very delicate handling. The framework is clad in asbestos cement sheets and has large panels of patent glazing ; both the cladding and the glazing had to be supported at closer centres than is normal, because of the high winds experienced on this part of the coast line.

The Future

More and more attention is now being paid to the use of nuclear energy for the production of useful power. The initial steps in this direction have already been taken with the construction of the thermal reactors at Calder works, and the proposal to construct a fast reactor at Dounreay.

The cost of electricity generated from thermal reactors is expected at first to be in the neighbourhood of a penny a unit—that is, 50 per cent higher than the average cost of generation from coal-fired power stations at the present time. In view of the fact that the predominant item in these costs is the capital outlay, it is confidently expected that reductions of 20 per cent or so can be made in the next ten years. The line of development will be towards the operation of reactors at higher temperatures, and towards a more efficient burn up of the fuel.

It will be obvious that the civil engineering work in reactors forms a major part of the capital outlay, and that the concrete work, in particular, is an expensive item. It seems inevitable that the accurate work in the construction of the reactor should be reflected in the concrete work, as the latter is really part of the reactor. Every effort is being made to localise this effect and to confine it to one face only. Large economies can be effected in this way provided that they are allied to an economic solution to the thermal problems.

The provision of a thermal shield made out of heavy steel plating is an expensive item, and, where an air passage is necessary between the plates and the concrete face, also tends to increase the cost of concrete work. The substitution of refractory materials for this steel plate is a possible source of economy, provided that they will stand up to neutron bombardment and consequent heat generation, and will act as an integral part of the concrete biological shield.

Finally, the shape of the shield has an important bearing on the cost, in that the possibility of cracks developing from shrinkage and temperature effects controls the method of construction and also the amount of reinforcement. The adoption of profiles to a more or less circular plan would assist in making the control of construction less restricting, and would also reduce the reinforcement required.

Conclusion

Although the work described has been carried to a successful conclusion, the author is very conscious of the fact that much of the design work has not been firmly based on research information, even in the general field of structural engineering.

In all, three chimneys or ventilation shafts have been constructed to heights of more than 400ft. It would be interesting to know whether the wind forces assumed at this height are in agreement with those being experienced. Their distribution around the shell was based on experiments on much lower heights of chimney, and yet this distribution is important in the case of the ventilation shafts, particularly at gallery level. In many of the structures it has been necessary to use monolithic concrete designs, even when subjected to temperature effects, without it being possible to obtain any reliable guidance on the real stresses set up thereby.

The development of power plants throughout Britain, as envisaged during the next twenty years, will lead to the active participation of many more engineers in this work, and the author looks forward to the rapid development of the technology associated with it. Undoubtedly, the reactors and chemical plants now being built will look clumsy and costly in 100 years' time, but it is to be remembered that mistakes leading to accidents with such potentially dangerous materials can easily deal a mortal blow to the development of nuclear energy.

Dual Trace Cathode-Ray Oscilloscope

A new general-purpose oscilloscope with facilities for dual trace working is being made by the equipment division of Mullard, Ltd., Century House, Shaftesbury Avenue, London, W.C.2. It has wide-band amplifiers, sweep expansion and stabilised h.t. and e.h.t. supplies. A tubular steel movable floor stand and an oscilloscope camera can be supplied as accessories.

The facility for dual trace working is provided on a conventional 5¼in tube by means of two identical Y-amplifiers and an electronic switch. Each amplifier is switched through to the cathode-ray tube on alternate sweeps, the electronic switch being operated during flyback. There is no interaction between the channels, each of which has a frequency response from 10 c/s (1 db down) to 4 Mc/s (3 db down). The rise time of the amplifiers is 0·1 microsecond. Identical attenuators embodying close tolerance high stability components are provided for each channel ; they permit the sensitivity to be adjusted from 0·02V peak-peak/centimetre to 100V peak-peak/centimetre in twelve steps. The frequency response of the amplifier channels remain constant for all attenuator settings and voltages can, it is stated, be measured within 5 per cent. The dual trace facility can be switched out when not required.

The Miller time base can be free-running, synchronised or triggered, and the sweep velocity is variable between 10cm per microsecond and 0·1cm per millisecond.

Expansion of the sweep length can be effected in three switched steps to 10cm, 20cm and 50cm. Velocity adjustments have negligible effect on sweep length. Time can be measured with an accuracy of ±10 per cent. The time base output stage can also be used as an X-amplifier with a sensitivity of 0·7V per centimetre and a bandwidth of 2 c/s to 300 kc/s.

An aluminium alloy cabinet (height 14in, width 10·5in, depth 27in, weight 60 lb) houses the oscilloscope, which is self-contained. The power unit, which is located at the rear of the case, is shielded from the tube. It is easily removable for maintenance, connections to the rest of the oscilloscope being by plug and socket. The amplifiers and time base units are easily accessible. There are no electrolytic capacitors and the oscilloscope is suitable for semi-tropical use.

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RAILWAYS AND INDUSTRY

It has been hitherto one of the peculiarities of the railways of this country that much of the heavier and more important engineering work has been carried out in railway shops. The strong individuality of pre-grouping days was in part responsible for this practice; for locomotives in particular it had the effect of making the manufacturing industry of this country dependent almost entirely upon overseas orders for its livelihood. Locomotives of all kinds form an important section of this country's heavy engineering export trade, and it has been often pointed out that a steady flow of orders from the home market would enable the manufacturers to keep their plants abreast of modern requirements and thus make them the better able to compete in world markets. While the railways were privately owned one could to some extent understand the reluctance of managements to depart from their traditional practice, while in the years immediately following nationalisation so much in the way of co-ordination and standardisation was being attempted that a major change in policy seemed unlikely. But now, with the prospect of a clean breakaway from steam to electric and diesel traction, the opportunity has come for a far closer integration of policy, in which two Ministries—the Board of Trade and the Ministry of Transport—could work in close co-operation for the benefit of the country as a whole. The locomotive manufacturers, in some way anticipating the change on British Railways, have been actively planning the expansion and development of their facilities, and they are now well placed to build any new types that may be required. By placing orders with them the British Transport Commission would be not merely implementing its own plan of modernisation, but making a major contribution towards the sustaining and improving of our export trade.

It is all the more disturbing on this account to learn that there are proposals afoot for purchasing large numbers of diesel-electric locomotives from abroad. In the recent Parliamentary debate on the railway modernisation plan, Viscount Hinchingbrooke remarked that he would have no objection to the importing of locomotives from America, and far from being a chance remark by a private Member, keen to press on with the modernisation plan, it appears that this is what the Commission is actually contemplating. We feel that when they realise the full significance of such a proposal there will not be many Members of Parliament who would agree with Lord Hinchingbrooke. The mere suggestion leaves one aghast! We cannot conceive on what grounds such a policy could be based, having regard to the great disservice it would do to a section of British industry; but if quick delivery is the object in view, to aid in the rapid superseding of steam traction, then to the disservice to industry will be added much difficulty in the running of the trains. One can quite appreciate the desire of the Commission to implement its proposals as soon as possible, in a spectacular manner. But we are only too well aware of the difficulties experienced in keeping a few closely watched diesels in service from sheds grown old in the service of steam, and nothing would be more embarrassing to operating staffs than to flood British Railways with foreign-built diesel-electrics before running-shed and maintenance facilities had been properly developed and the staff trained.

While from the viewpoint of immediate publicity there might be something to be said for hastening the change in main line express passenger motive power to the point of precipitancy, on every other ground there is nothing. As a recent article in our columns pointed out, first line steam power is in a thoroughly healthy state, and well able to carry on for some years. What is far more urgent is a drastic modernisation of traffic regulation methods, to eliminate the signal delays that are the bugbear of train operation. If the Commission could do something quickly to solve that problem it would earn the gratitude of every one using the railways. But to return to motive power, the process of gradual replacement of steam envisaged in the B.T.C. plan offers a unique opportunity to build up a new and efficient structure of locomotive engineering policy in this country, with the fullest co-operation between the railway engineers and the manufacturers. As the railways themselves develop their service and maintenance organisation, testing and thoroughly proving the new prototypes, so the builders could expand their own manufacturing capacity to deal with the full weight of orders that should follow. As in the past nothing but the best and most reliable should be good enough for British railway motive power. There is no question but that British industry can supply it. By foreign purchases the British Transport Commission would sidetrack one of the oldest and most expert of our heavy industries. It would do more. The loss of prestige, perhaps even more than the loss of orders, would be a crippling blow to our export trade.

SCALE AND CORROSION IN INTERNAL COMBUSTION ENGINES

It was a saying as long ago as the fourth century that *Intus hostis, intus periculum* (Within is the enemy, within is the danger). In the case of internal combustion engines the danger is not only within but can be even more threatening without. This reflection arises from a perusal of the paper, "Prevention of Scale and Corrosion in the Water Cooling Systems of Internal Combustion Engines," which was read before the Diesel Engine Users Association on February 17th, by Mr. E. L. Streatfield. There was a time when it seemed that corrosion difficulties were confined—so far as relates to heat engines—mainly to steam boilers. The engine was protected, indeed, by the boiler, and far from requiring external cooling, was lagged to maintain its cylinders in a hot condition. With the incoming of the internal combustion engine the corrosion and scaling problems which had afflicted the boiler were transferred to the engine and not being able to arrive at engines insensitive to corrosive constituents in the cooling water, we are obliged so to treat the water (where corrosive or scale-forming) that it may not be harmful to the engine. We can also contribute to security by using a closed circuit cooling system with heat exchanger. Mr. Streatfield tabulates information as to the typical analyses of water from the various sources, such as town mains, wells, rivers, canals, moorland areas and the sea. Town main water and chalk well water, used as cooling water, tend, he says, to be scale-forming rather than corrosive. River and canal waters are usually scale-forming and may contain so much suspended matter as to require filtration before use as engine cooling water. "Moorland waters of a peaty character are soft and corrosive and also usually contain suspended matter which may be iron oxides. Sea-water is both

scale-forming and corrosive." It is further emphasised that in addition to the harmful potentialities mentioned above, "contamination of cooling water by oil can have a very serious effect as a result of the oil adhering to metal surfaces and causing overheating."

Having catalogued and commented on the harmful constituents of the cooling water, Mr. Streatfield offers suggestions as to how best to protect the engine from their attack, and a very interesting table in the paper sets forth the effect, on the dissolved salts in water, of the three main softening processes the lime-soda process, the base exchange process, and the de-ionisation process respectively. According to the author, softening by the lime-soda process reduces the dissolved salts by 20–25 per cent, the reduction being greater the higher the temporary hardness. Softening by the base-exchange process results in a slight increase in the dissolved salts which will be greater the higher the content of magnesium salts. The temporary hardness is converted to sodium bicarbonate which decomposes with heat to give carbon dioxide with consequent corrosive effects. The process of de-ionisation removes substantially all the salts from the water. But that process can only be economically applied for the treatment of fresh water and not for sea-water. It will be gathered from the above brief citation that the engine user will find Mr. Streatfield's a most informative paper. We would remark, however, that the security of internal combustion engines is always dependent upon the quality of the maintenance given to them and on the adequacy of the installation accessories. It has been well said that "The greatest evils have had their rise from somewhat which was thought of too little importance to be attended to." Again, the engine builder can make his contribution by rendering access for cleaning as effective and convenient as possible. The number, position and area of the cleaning holes in cylinder jackets, cylinder heads, water cooled pipes, &c., are matters which have an important bearing on engine maintenance and safety. A further factor calling for detailed attention in the larger monobloc engines is the planning of the cooling water spaces and passages, so that the cooling throughout the engine may be reasonably uniform.

Mr. Streatfield remarks that while the temperature of the bulk water outlet from an engine cooling system may be 120 deg. to 160 deg. Fah., "the actual temperature in the hottest parts of the cooling system in the vicinity of the cylinder heads will be very much higher, resulting in heavy scale formation in the most constricted parts of the cooling water circuit." It is very true and we are well-advised to bear in mind that it is much easier to inject fuel into an engine than to remove the heat of combustion, only a fraction of which gets out in the form of work. The higher the speed and the lighter the weight the more urgent becomes the need to avoid overheating of the engine. The path through the piston and piston rings to the liner is tenuous enough without being blocked by scale and there can be no excuse for ignorance as to the cause and consequences of ring sticking. The heat must either be allowed to get away or the overheating will damage the engine in its most sensitive parts. While circumstances may render it imperative—as in rail traction engines—to reduce weight and/or space requirements to a minimum, it still remains obligatory to protect the engine from breakdown due to overheating. In his recent Thomas Hawksley Lecture, Dr. F. P. Bowden, referring to the damage done by friction, remarked that one of the greatest limitations is temperature. He looked forward to the time when it would be possible to run things faster and faster and hotter and hotter. "The engineer," he said, "would like to run bearings and to slide surfaces at 1000 deg. Cent. and at very high speeds. Why should he not?" Until discoveries are made which will permit of such performances, the engineer has to work with what he has and among his problems are those of keeping the engine cooling spaces clean and of maintaining the heat dissipating capacity of oil coolers and heat exchangers. Too often the cleaning of the oil cooler involves—like the cleaning of other parts of the engine—an unnecessary amount of dismantling and an excessive expenditure of time. If the engine and its accessories are not kept in a condition which enables them to operate satisfactorily, trouble is certain and we shall be wise to remember that failure to deal adequately with the thermal problems is a sure road to breakdown. *Intus hostis, intus periculum.*

Obituary

SIR JOHN BOWEN, C.B.E.

We regret to record the death of Sir John Bowen, which occurred suddenly on Friday last, March 4th, at his home in Portsmouth Road, Kingston-on-Thames. He was formerly engineer-in-chief of the Corporation of Trinity House, from which position he retired three years ago. Sir John, who was born in 1886, was the son of the late Mr. John Bowen, borough engineer of Reading. He was educated at Westminster School and graduated in the University of London. During the first world war, Sir John served in France with the Royal Engineers, and following his demobilisation he joined the engineering staff of Trinity House. He spent the remainder of his professional career there, being appointed to the position of engineer-in-chief in 1924. Sir John was created C.B.E. in 1945, and the honour of Knight Bachelor was conferred upon him in 1952, following his retirement from Trinity House at the beginning of that year. For many years, Sir John contributed a chapter on "Channel Demarcation" to *Kempe's Engineer's Year-Book*.

Literature

Residual Stresses in Metals and Metal Construction. Edited by W. R. Osgood. London: Chapman and Hall, Ltd., 37, Essex Street, W.C.2. Price 80s.

This is a collection of papers prepared for the Ship Structure Committee of the American National Research Council through its Committee on Residual Stresses. While the emphasis is clearly on the possible contributions of residual stresses to brittle fracture, most of the twenty-two papers have application and interest over a far wider field. The authors come from a number of countries and have had a free hand in discussing the subject as they see it. The origin and causes of residual stresses, existing in a structure or machine and their magnitude and distribution in relation to the circumstance which gave rise to them are very thoroughly covered and, unlike so much which has been written about residual stresses, the papers deal with practical cases, or speculate on the effects of such stresses, in a realistic manner.

There has been much speculation about the possible influence of residual stresses on the brittle fracture of welded ships, and it has often been contended that high residual stresses are an important contributory cause of catastrophic brittle failures of welded ships. This view now has lost much of its support, and the contribution from the British Admiralty Ship Welding Committee concludes that "Continued experimental researches in the testing of various forms of welded construction have failed to establish that locked-up stresses impaired their strength." MacGregor, in a paper on "The Significance of Residual Stresses" refers to experiments in which it was shown that where plastic flow can take place under cyclic stress the residual stresses gradually decrease; but the interesting problem is that in which the constraint is such (as in a welded ship structure) that only very limited general plastic flow is possible. Indeed, other experiments have been reported to show that cyclic stresses can raise the transition temperature range and this may be an important problem from the point of view of a ship's structure—i.e. even if the steel was satisfactory as regards notch ductility when accepted, these results suggest that it may become unsatisfactory with time.

The Committee on Residual Stresses attempts to summarise the papers in a twenty-two-page statement at the end of the book. While it does not reach any general conclusions it does focus attention on the important problems and discusses some of the failures which seem to depend for their explanation upon the fact that high residual stresses were present. It is finally concluded that "Residual stresses may assist in the initiation of brittle fracture in ships and affect adversely the fatigue strength of ship steel. The effect of residual stresses (reaction stresses) on the propagation of ship fractures is less clear; but unless spontaneous fractures can be explained in the absence of residual stresses, these stresses cannot be considered unimportant. All this is not to say that a more fruitful source of reducing ship fractures may not lie in improved steel or elsewhere than in going to great lengths to lower the residual stresses."

The Design of Cylindrical Shell Roofs. By J. E. Gibson and D. W. Cooper. London: E. and F. N. Spon, Ltd., 15, Bedford Street, W.C.2. Price 35s.

Since the war in particular a great number of shells have been designed and constructed and an increasing number of engineers has entered this field. This is in happy contrast to the situation which existed before the war when the design work for such structures in this country was carried out in Germany. Nevertheless, even in this country the design of such shells has tended to be considered as a secret to be guarded and no book (save one) has been forthcoming from those in this country actively engaged in this class of work. The book is, therefore, a welcome addition to the literature on the subject for the number of books in English can be counted on one hand. After reading the book one is, however, left with the thought that experience is almost as important as theory in this subject and that although the book is professedly aimed at the design engineer it will only benefit him to the extent of putting the theory before him—

he must also obtain practice in design and execution of such work.

The authors deal exhaustively with only one problem—that of the long shell—but consider it with three edge conditions: with no edge beams, with reinforced concrete beams and, finally, with prestressed beams. The first is rarely applicable in practice, the second is more usual, while the third is coming more and more to the fore. The treatment of the last condition is probably the first that has been published.

The usual equations are derived, together with the compatibility equation for the shell (following Lundgren's method using the variable w) and a method of computation together with a worked example for such a shell is given. It is a little unfortunate that it is only on the last page of this section that it is demonstrated that such a shell is not possible without edge beams!

After a comparison with elementary design, an edge beam theory is developed and the relevant equations are combined with those developed for the shell for the second case they consider. It is, of course, this combination which gives rise to the real difficulties in a rigorous mathematical analysis of shell structures, for upon the assumptions made at this juncture depends whether the solution is tractable or not. It is felt that a capability of handling the mathematical tools is not enough but that one has to have a clear perception of the way a shell behaves and this calls for a sound engineering judgment.

One wonders whether this has always been appreciated and whether the assumptions made (which Professor Marshall in his preface says can be "fully justified") are those which are necessary to solve the equations rather than those which describe the behaviour of the shell. (Three simple instances may be cited—is Poisson's ratio equal to zero? Is reinforced concrete a homogeneous material? Should twisting be neglected in the edge beam? The effects of the first and last of these assumptions not being true are dealt with summarily towards the end of the book.) A general criticism may be made at this point that the greater part of the book deals with a simple shell which is not so common in practice and it is only at the end that the more complex and usual shells are considered and here the poor designer is left with very general equations and no worked examples. North light shells are dealt with in a couple of pages, making a very arbitrary assumption which is surely not correct, that the effect of window columns may be ignored. (Two minor textual points may be noted. Fig. 52 does not agree with the text and must we have Lee-McColl consistently?) A list of symbols would also be desirable in any future edition rather than an appendix on r.c. design.

We consider that although the book serves a useful purpose in setting out the mathematics of the subject, particularly as Jenkin's book is out of print, the average designer would find greater help in a book more on the lines of the A.S.C.E.'s book "Design of Cylindrical Concrete Roofs," or better still, that of the recent paper by Tottenham in which tables relieving the work of the computer and practical hints based on a rich experience of much design work are given. Such a set of tables was promised by the late Professor Dischinger but it never materialised.

Until a designer has computed or obtained such a set of tables he will always be at a disadvantage in competitive design since a large effort is required not only in the design but also in the checking. Perhaps we may look forward to a book on these lines?

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

HYDRODYNAMIC LUBRICATION OF ROLLER BEARINGS

SIR,—In your issue of September 3, 1954, there appeared a letter by A. A. Milne and J. A. Cole, in which they contribute to the discussion on my article under the same title in your issue of June 25, 1954. I wish to make the following remarks on their criticism.

The authors start by saying my article is an application of the "elastico-hydrodynamic" theory of lubrication discussed by Professor Block (*Annals N.Y. Acad. Sci.*, 1951, 53, 779-804), and that my contribution is essentially to place earlier qualitative ideas on a quantitative basis. Quote from the above reference: "Only rarely can this geometric handicap of the gears (a very small radius of relative curvature in comparison with what it is in journal bearings) be overcome by choosing such a high viscosity of the gear oil that, for a given tooth rubbing speed, the product (viscosity-velocity) becomes sufficiently great (to form a hydrodynamic film)." Obviously, Block does not even admit the possibility of the type of the extremely high pressure lubrication with which my article is concerned. It may be interesting to note in this connection that the authors of the letter must be well aware of the fact that I formed my ideas on the subject before the appearance of Block's article and without reference to any earlier work. Incidentally, I prefer the term "hydroelastic" to "elastico" or "elasto-hydrodynamic."

The authors proceed to say that my analysis is marred by several errors, the most serious one being my assumption of $\delta=0$ and $\alpha=$constant. But I have never asserted that α is a constant, only that it is so *approximately* in the region of heavy specific stresses. The authors claim that δ must have a finite value. I disagree, the reason why δ should not be finite but always zero is the assumption that the elastic deformation follows the Hertzian law. This law demands that the elastic forces normal to the surface should be distributed symmetrically, with their resultant right in the middle of the flat. As δ is the distance of the resultant from the middle of the flat, it must be zero.

Having assumed a finite δ the authors then assert that δ and α are fully determinate from . . . consideration of the equilibrium of external forces acting on the cylinder. By that they mean that the cylinder with the flat should be regarded as a rigid body capable of rotary displacements as a whole, subject to the action of the forces F, W, N, and moments M, δN, RT, about the axis of rotary freedom (see their Fig. 1). One cannot say that they do not regard the flat as a part of a rigid body simply because the flat is given the freedom of small angular displacements together with the body of the cylinder in order to find its equilibrium position, which is when all the forces and moments come to balance. Apart from the above small angular displacements, the flat is, of course, stationary. How is this to be reconciled with the continuous rotation of the cylinder (velocity U)?

There remains to be pointed out that the forces acting along the flat, such as T in the letter, cannot influence the position of the flat in the manner the authors suppose. This ineffectiveness of T is a matter of principle, the lack of a rigid bond between the rotating surface and the stationary flat. A variation of T can, of course, affect the velocity U. To put the argument differently, suppose that T is moved along the periphery out of the deformed region. This would not alter its turning moment on the cylinder. Why, then, should such a shift be able to affect the position of the flat in the proposed scheme?

The authors say further that the system of forces in Fig. 5 of my article is incomplete and that the derivation of equations (21) to (23) is meaningless. My Fig. 5 contains the normal forces N, the tangential forces T, the latter being resolved into S and F. The flat is said to be held in the equilibrium position on the periphery by two opposed moments N and $bS/2$, both originating in the unbalanced forces normal to the flat. Otherwise, the flat is said to be free to move along the periphery of the cylinder. What is then missing?

Equations (21) to (23) are not meaningless; they are an estimate of a small effect of T on the equilibrium value of δ and α. The part of the elastic body which delimits the flat is subject to a small tangential strain due to the action of T on the surface. This local strain gives rise to a compressive stress in the tangential direction in the region surrounding that end of the flat towards which T acts, and a corresponding tension stress around the other end of the flat. Because these stressed regions include the edge between the flat and the circumference, there result unbalanced forces normal to the flat. In the first approximation there results no distortion but a displacement of the flat. It is easy to show that the displacement is in the opposite direction to what the authors suppose it to be. However, the displacement is found to be negligibly small. In this sense the postulate $\delta=0$ remains valid.

The authors further state that my equations (21) to (23) are unnecessary because the relationship between fluid and elastic forces has been predetermined by the initial assumption of the mode of elastic deformation. Not at all: tangential fluid stresses were not predetermined by this alone, but only in conjunction with equations (21) to (24), as explained in the preceding paragraph.

Further, the authors say that there appears to be inconsistency in the consideration of conditions outside the flat. In one place it is assumed that there are no significant normal forces beyond the flat, and these forces are neglected in obtaining the total load N (equation (17)) and in the coefficient of friction (equation (36)); yet the normal and tangential forces on the curved surfaces appear in equations (30) and (33). The reason why the forces beyond the flat are neglected in the first case is that for heavy loads they are negligible. Equations (17) and (36) are said to apply to heavy loads only. But the tangential forces beyond the flat are never negligible; it is readily seen from equations (30) to (32) that their omission would just about halve the estimated friction coefficient.

The latter is an obvious reason why one should not follow the next proposal by the authors, that all forces outside the flat should be treated as negligible throughout. There is, however, a more fundamental reason for the rejection. The fluid pressure built up along the inflow region (the space between the curved surfaces adjoining the inlet to the fluid wedge, i.e. to the Hertzian region) is the sole cause of setting the flats at an angle. T being inoperative and δ always negligibly small, there is no other mechanism available with which the formation of the fluid wedge can be effected. Were the fluid forces along the inflow region to be negligible throughout, the fluid wedge in the Hertzian region would flatten out ($\alpha\rightarrow1$) and the separation between the flats would collapse to nothing.

Then the authors say that a number of lesser criticisms might also be made, such as the unjustifiable omission of tangential stresses from equation (30) and the curious derivation of equations (13) and (31). The tangential forces (*cf.* my Fig. 6) cannot be included in equation (30), and it is easy to show why not. When a cylinder rolls on a plate without sliding, the plate being stationary and the cylinder being pushed along by the force f applied to its axis, the forces T obviously do not do any work, except perhaps for second-order small quantities. T acts on that part of the circumference of the cylinder

which is stationary with respect to the plate (no-sliding condition). As T does not do any significant work it cannot have any effect on friction. To put the argument differently, imagine that in order to arrest sliding the cylinder is geared to the plate. The plate is of the same width as the cylinder and has a toothed rack back and front. A gear is fixed to each end of the cylinder, its pitch diameter is a trifle smaller than the cylinder. If the cylinder is now pushed along, T acts on the level with the pitch circles and is absorbed by the teeth of the racks.

The equation (31) is not in any way curious. If anything, it is a more accurate version of equation (30), a solution of the same problem in terms of tangential fluid forces. The cylinder is fixed in space but it rotates with peripheral velocity U; the plate moves along it with the same velocity. I can guess the authors objection to the factor 2 in the formula. But how is it to be avoided when one driving force has to be applied to the cylinder and another to the plate, in order to maintain both the movements ? The present solution is more accurate than equation (30) because now all normal forces become inoperative. As it can readily be shown from Fig. 6 of my article, all normal forces resolve in the stationary axis and do not do any work whatever.

I agree that the derivation of my equation (13) is somewhat curious ; I would welcome an attempt by anyone to deal earnestly with this point of my theory. But I am certain that substituting something else to my formula (13) is not indispensable, at any rate not at the present early stage of our understanding of the host of physical assumptions, with which any such analysis has to begin.

The authors now present their "revised theory." Needless to say, they simply put together all the assumptions and proposals already discussed. Any one of these would knock out all physical meaning from my theory. I note some further errors : the angle between the flats should be "a" in their drawings, not α. The left-hand side of their equation (11) should be $\frac{3\pi}{8}\left(\frac{E}{1-\nu^2}\right)\frac{\eta U R_1 B^2}{W^2}$. Their equation (12) should be $\mu=\frac{h_1(\alpha-1)}{L}$.

The authors conclude from their analysis that α varies with the conditions of operation and note that a similar conclusion was reported by Block (*Journal Inst. Petroleum*, 1952, 68, 673). Not at all ; Block's speculations refer to the possibility of a slow variation of α, of the type which I am neglecting in conjunction with heavy loads, whereas the authors' conclusion is not well grounded. Referring to this article by Block, it is interesting to note that his Fig. 2 (reproducing Peppler's numerical solution of the general problem concerned with) contains the "near-Hertz" pressure distribution curve, which is not unlike Fig. 7 of my article.

W. LEWICKI
Imperial College of Science and Technology, Department of Chemical Engineering and Applied Chemistry, February 17th.

IMPROVING LOCOMOTIVE PERFORMANCE

SIR,—The article in THE ENGINEER of February 4th, by Mr. Nock, comments on Test Bulletin No. 8 published by the British Transport Commission dealing with the smokebox alteration carried out at Swindon on a "V2" class engine and the tests made beforehand and afterwards. These show a remarkable increase in the steaming capacity of the boiler by "Swindonisation" of the smokebox arrangement, but those concerned in the test stuck closely to their brief, notwithstanding some glaring faults revealed in the course of the trials. Thus, we hear of irregular beats, oscillation of tender drawbar and difficulty in starting from rest, which indicator diagrams show to originate in the uneven distribution of steam between the front and back strokes of the middle cylinder. Yet nothing was attempted to rectify matters, though the stationary test plant was available for a thorough investigation ; but the whole thing was dismissed on page 6 of the report in the words: "The valve gear conjugation is responsible for the unevenness of the steam distribution to the inside cylinder"—and it was left at that, as though nothing further could be done about it, other than to mask the longitudinal oscillation by "redesign of the intermediate and tender drawbar details" (see page 7).

The Gresley form of conjugated gear has been in use for thirty-five years and has been applied to a large number of engines, and so, on the whole, it must have given satisfaction, though we do hear at times of difficulties with the valve setting of the middle cylinder in individual engines due to wear or to overrunning of the valve beyond its intended travel.

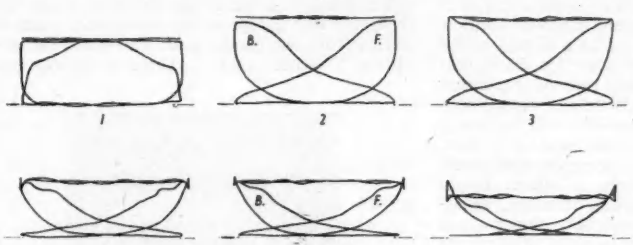


Diagram No.	Regulator opening	Reverser notch	Lb/sq in steam chest pressure	Superheat, deg. Fah.	M.p.h. relative speed	M.E.P., lb/sq in	
						Back	Front
1	Part	6	125	500	Starting	108·7	115·6
2	Full	2¼	180	600	35	70·8	73·8
3	Full	2¼	185	580	39	69·5	65·7
4	Part	2¼	120	570	62	32·3	32·7
5	Part	2	125	550	62	28·7	28·7
6	First valve	1½	80	550	67	12·0	13·5

In the case of the "V2" engine under test, the mileage was low and so wear can be ruled out. Some of the worst diagrams were obtained at low speed and, therefore, inertia forces played no part. Yet according to Table II, giving the valve events, a most satisfactory distribution should have resulted in all three cylinders in cut-offs ranging from 66 to 15 per cent.

The valves were, presumably, set when the engine was cold, and therefore some correction should have been applied to the setting of the middle valve to neutralise the effect of the lengthening of the valve spindles of the outside valves by thermal expansion. If this correction is, in fact, done in the shops as a matter of routine, was the amount sufficient in view of the high steam temperature of 700 deg. Fah. or more entering the steam chest in the "V2" class ?

By driving the conjugated gear through an extension of the outside valve spindles which are exposed to high temperature over much of their surface, any lengthening of one spindle sets the middle valve back by that amount through the leverage, and to this is added the extension of the other spindle. Thus, if the expansion is $\frac{1}{16}$in on each side, the middle valve will be displaced from its central position by $\frac{1}{8}$in, and that is quite sufficient to account for the unevenness of the indicator diagrams. Since the lap of the inside valve has been increased to $1\frac{1}{16}$in with the intention of reducing the lead to $\frac{1}{16}$in, a $\frac{1}{8}$in displacement would result in the valve being $\frac{1}{16}$in "blind" when the piston is at the end of the stroke. The extension by heat is likely to be greater at the longer cut-offs because the exhaust steam surrounding the rods will also be higher in temperature owing to some superheat remaining.

In arrangements where the conjugation is driven from attachments at the back of the cylinders, this disturbance due to thermal expansion is obviated, and perfectly good results and equal distribution between front and back strokes of the middle cylinder obtained. To illustrate this I reproduce some indicator diagrams taken from the middle one of three cylinders operated through a conjugation connected in this way. These are as nearly equal as possible in m.e.p. front and back in every case. The speeds given are not the actual, but the equivalent speeds resulting if the wheels had been 6ft 2in diameter, as in the "V2," in order to compare with the diagrams illustrated in Mr. Nock's article.

In the absence of wear, any overrunning of the middle valve is due to lack of rigidity in the valve gear layout as a whole, centring on the bearings of the two quadrant links of the Walschaerts gears and going back to the return cranks and crosshead arms of the two primary gears and to the anchorage of the whole at the reverser in the cab. The middle valve, being at the outer end of this system, will experience the most deflection under inertia loading. The attainment of sufficient rigidity is a matter of detail design over the whole layout.

Apart from any question of over-travel, it is characteristic of conjugated gears to produce a higher m.e.p. in the middle cylinder than that obtained with the primary gears as speed is increased and cut-off shortened, so that at the higher speeds the middle cylinder is doing more work than either of the other two.

This is not so much due to any lengthening of cut-off point as the production of a fatter diagram for the same cut-off point as for the outside cylinders. The attempt to correct this by increasing the lap of the inside valve results in one end of the inside cylinder being virtually blanked-off should the valve be displaced from its central position.

If it is thought necessary to decrease the work of the middle cylinder I suggest that a better way of doing this would be to reduce the travel of the valve, as compared with the outside valves, by a slight alteration to the proportions of the levers comprising the conjugation, instead of rigidly adhering to the 2 : 1 and 1 : 1 proportions as at present.

H. HOLCROFT
Chipstead, Surrey, February 5th.

Books Received

Reinforced Concrete Arch Design. Second edition. By G. P. Manning. London : Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, W.C.2. Price 30s.

Data Book for Civil Engineers—Field Practice. Second edition. By E. E. Seelye. London : Chapman and Hall, Ltd., 37, Essex Street, W.C.2. Price 60s.

Safety in Industry. By D. I. Macfarlane. Published for *Machine Shop Magazine* by Iliffe and Sons, Ltd., Dorset House, Stamford Street, London, S.E.1. Price 7s. 6d.

Production Control. By J. Motterham. Published by the Industrial Administration Group of the Guild of Students of the College of Technology, Birmingham. Price 3s.

Radioisotope Conference, 1954. Proceedings of the second Conference, Oxford, July 19th to 23rd. Edited by J. E. Johnston. London : Butterworths Scientific Publications, 88, Kingsway, W.C.2. Price 45s.

Stench Capsules as a Warning of Overheating of Mining Equipment. By G. E. Curzon and H. S. Eisner. Published by the Technical Information Section, Safety in Mines Research Establishment, Portobello Street, Sheffield. Price 1s. 9d.

Electrical Engineers' Exhibition

No. I

THE fourth Electrical Engineers' Exhibition, organised for the Association of Supervising Electrical Engineers, will be opened by Lord Citrine, chairman of the British Electricity Authority, at Earls Court, London, on Tuesday, March 15th, at noon. It will remain open daily until Saturday, March 19th.

There will be more than 230 exhibitors, an increase of more than one-third compared with last year's total. The British Electricity Authority and nine Associations will be represented, including the Electrical Research Association, the British Electrical and Allied Manufacturers' Association, the Cable Makers' Association and the British Electrical Development Association.

Electric motors and their application will provide the main theme of the exhibition and at the end of the Hall there will be a display called "Motor Way," which will allow for the exhibition of one example of every type of specialised electric motor made in the industry. Apart from motors and starters, the exhibits will include a variety of cables and wires, trunking and busbars, lighting fittings and lamps, domestic appliances, switch and fusegear, relays, rectifiers, transformers, industrial electronics, furnaces, radio-frequency heating, accumulators, blowers and fans. Two awards will be made to the manufacturers who exhibit "the most outstanding domestic labour-saving and industrial devices."

A brief description of some of the items to be exhibited is given herewith.

Ferranti, Ltd.

A high-speed electronic test set for testing a.c. meters will be demonstrated by Ferranti, Ltd., Hollinwood, Lancs. This equipment is available as a complete unit. Alternatively the controls and amplifier panels can be supplied separately as a means of modifying existing test benches to make them suitable for high-speed testing and it is this latter facility that will be specifically demonstrated.

The principle of the method is to compare the speeds of the meters under test with the speed of a substandard meter, which is in this case a precision two-disc balanced torque meter, thermostatically controlled at a constant temperature. The lower disc is used as the driving and braking disc. There are 200 gear teeth cut on the periphery, of the upper disc, which acts as a light shutter, interrupting light falling on a photoelectric cell, the output being amplified and applied in two different ways. In the first method a synchronous motor is coupled to a light interrupting disc, thus giving a beam of light of high intensity which can be used on high loads to test stroboscopically meters carrying the usual patterned disc. This lamp is arranged on a system of rails so that it can be placed over any meter. In the second method another synchronous motor is geared to drive pointers, the rate of count being proportional to the substandard speed, thus making every counter a slave substandard. The counters are mounted on a panel below the meters under test.

To enable one substandard to be used on all kinds of meters which have differing constants and stroboscopic markings, a decade current transformer is interposed between the secondary of a multi-range c.t. whose primary is in series with the meters under test and the substandard. A known fraction of the load current flows in the primary of the decade c.t. with a variable number of turns, and since the secondary turns are fixed, the secondary current (and hence substandard speed) is variable.

Calibration consists of stroboscopically testing the meters on high loads, and timing the meters on low loads, using the counters. The counters are used like stop-watches in the conventional stop-watch and watt-meter method, and it is found that one tester can start twenty counters in sequence before the first meter has completed many revolutions on low load, when the counters can be stopped in sequence. There is, of course, no need to steady the load when either strobing or timing, as any variation in load reacts identically on both substandard and meters under test. In general, the errors on twenty meters can be determined on low loads to an indicated accuracy of one part in a thousand or better, in three or four minutes.

On the same stand there will be a "Fridge-Heater," consisting, essentially, of a heat pump designed to cool a larder and provide a supply of hot water for domestic purposes. A white enamelled sheet steel cabinet measuring 3ft by 16in by 16in houses the complete heat pump, comprising a motor-driven compressor mounted in a central compartment, condenser tubes fitted in a water tank in the base, and evaporator tubes in the upper portion (Fig. 1). The principle of operation is that when hot water is drawn off from any of the taps in the house cold water is drawn from the header tank into the "Fridge-Heater" water tank. There a thermostat

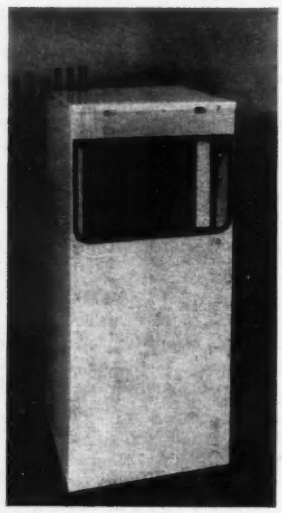


Fig. 1—Domestic heat pump combining the functions of water heating and refrigeration —Ferranti

switches on the heat pump; the refrigerant vapour is compressed to a pressure at which it is hot enough to be condensed, giving up its heat to the water surrounding the condenser coils. The liquefied refrigerant is then circulated via a capillary tube to the evaporator at the top of the cabinet. Air from the larder is blown by a fan over the outside of the gilled evaporator tubes. Here the refrigerant is evaporated by heat abstracted from the larder air before being returned to the compressor.

Operation of the heat pump continues in this way, water being circulated between the heater tank and the storage tank via the flow and return pipes, until all the water in the system is at 140 deg. Fah.; the thermostat then switches off the heat pump.

The quantity of heat given up by the vapour condensing is about three times the quantity of heat (supplied in the form of electricity) required to drive the compressor. The heat output is specified as being 4200 B.Th.U. (or 5 gallons per hour at 140 deg. Fah.) in the summer and 2400 B.Th.U. in the winter, the electrical loading being 250W to 500W.

The equipment can also be used for making ice in a compartment above the evaporator tubes. For this purpose a switch on the back of the casing is moved from "normal" to "ice," which switches off the fan. By doing this the temperature at which evaporation occurs is reduced to below the freezing point of water and ice cubes can be made. When used for ice-making the machine consumes more electricity per gallon of water heated and the rate of water heating is reduced, by comparison with the figures quoted above.

As can be seen from Fig. 1, the water connection fittings are at the top of the cabinet. They are of copper and provide for ½in flow pipe, ½in return pipe and ¾in cold feed pipe.

Henry Wiggin and Co., Ltd.

A new grade of nickel-chromium alloy for high-temperature furnace resistance elements is being shown by Henry Wiggin and Co., Ltd., Thames House, London, W.1. It is known as "Brightray H" and is a modified nickel-chromium alloy intended for elements operating within the temperature range of 1100 deg. to 1250 deg. Cent., which is beyond the value normally suitable for the existing alloy "Brightray S." The new alloy has been developed in the research laboratories of the Mond Nickel Company, Ltd., and is now in production by Henry Wiggin and Co., Ltd., in the form of rod, wire and strip. Some of the main properties of the material are given briefly herewith, based on information supplied by the manufacturer.

Oxidation resistance of the new alloy at temperatures above 1100 deg. Cent. is better than that of the standard 80/20 nickel-chromium alloy. Laboratory tests on strip 0·88mm thick by 14mm wide and on rod heated continuously in air to 1250 deg. Cent., gave lives of over 1000 hours—a considerable improvement compared with the standard 80/20 nickel-chromium alloy in similar conditions.

The specific resistance of "Brightray H" at room temperature is 126–130 microhms per cm^3; it increases by 3·6 to 4 per cent as the temperature is raised to about 450 deg. Cent., and decreases by 6 to 9 per cent between 450 deg. and 900 deg. to 1000 deg. As the temperature is further increased the specific resistance rises slightly, but up to 1300 deg. Cent. remains less than the value at room temperature. The density at 20 deg. Cent. is 7·8 to 8·1. The alloy has good high-temperature strength and does not become brittle in service. It thus combines improved oxidation resistance at temperatures above 1100 deg. Cent. and not exceeding 1250 deg. Cent. with the well-known advantages of "Brightray S."

Crompton Parkinson, Ltd.

Among the induction motors to be shown by Crompton Parkinson, Ltd., Crompton House, Aldwych, London, W.C.2, will be examples of the "NK" range of totally-enclosed fan-cooled motors. In these machines a variety of starting characteristics is offered. The standard "NK" slipring motor has a starting torque of 100 per cent full load torque with a starting current of 100 per cent full load current; higher starting torques with correspondingly increased starting currents can be provided for, if required. By fitting different rotors in the standard "NK" squirrel-cage motors a choice of three different starting characteristics can be obtained. Starting characteristics lower than standard can be provided in squirrel-cage motors, to meet special requirements.

In all cases the cooling system is dual. An inner cooling system, consisting of a fan at the driving end, circulates air through and behind the stator laminations and through the rotor core by means of specially shaped ports. An outer cooling system, consisting of a fan at the non-driving end, draws air from the atmosphere and blows it through stator core ducts at a high

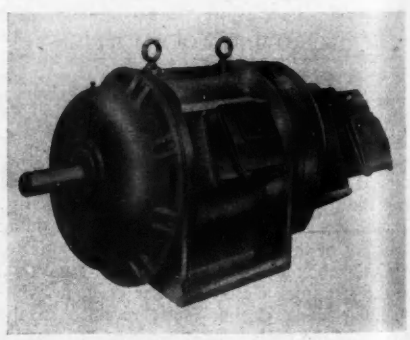


Fig. 2—Totally-enclosed fan-cooled induction motor—Crompton Parkinson

velocity (to minimise dust deposition), the air being exhausted at the driving end. Any size of pulley can be fitted without fear of obstructing the air intake which, as stated, is at the non-driving end. A typical "NK" motor is illustrated in Fig. 2; the complete range covers outputs from 80 h.p. to 600 h.p.

The exhibits will also include examples of Crompton Parkinson "A" type motors specially developed for use in domestic appliances. They conform to Canadian Standards Association requirements for domestic appliances and to B.S. 170 and 2048. They can be arranged for horizontal, vertical or angle mounting, and there is a choice of three positions on the end shield for the location of the "Thermatrip" overload device.

Among the stud-welding exhibits there will be a transformer-rectifier unit having characteristics suitable for both stud welding and metallic arc welding. The choice of outputs from this unit is by a three-position switch providing either stud welding up to ½in diameters or single-operator arc welding up to 400A or double-operator arc welding up to 200A each. In the latter position the outputs may be individually controlled and they are free from interaction.

The company's display of fluorescent lighting equipment is devoted to the recently introduced fittings, known as the Crompton "New-Range." These fittings, of which there are fifty-four to meet the individual lighting requirements of industrial, commercial and scholastic premises are all derived from two basic units, the complete range being built up by combining with one or other of these units, a selection from eight further components. Because only ten components are needed to form fifty-four different fittings, the company has been able to cheapen production and simplify installation.

British Thomson-Houston Company, Ltd.

A recent development in voltage regulation (using equipment known as the "Magnestat") will be the subject of a demonstration on the stand of the British Thomson-Houston Company, Ltd., Rugby. The "Magnestat" is a static amplifier consisting of saturable reactor and rectifier elements, and it is designed to control a large output by a small d.c. signal in the control windings. In the demonstration, a "Magnestat" voltage regulator of a size capable of controlling the output of a 30MW turbo-alternator set is shown in conjunction with a model of a turbo-alternator. Appropriate loads can be switched on to the output of the alternator and the control of the "Magnestat" on the output can be observed on suitable meters.

A typical installation is the one at Portsmouth power station of the Southern Division, B.E.A. (Fig. 3), where the "Magnestat" voltage regulator controls a 30MW turbo-alternator. Here the regulator is used in conjunction with an amplidyne exciter which provides the excitation of the main exciter on automatic control. The voltage regulator adjusts the excitation of the amplidyne field to keep the generator voltage within the prescribed limits of ±1 per cent. A high speed of response is obtained by adequate forcing of the amplidyne and main exciter field currents and by reducing the time constants of the magnetic amplifier and amplidyne to a minimum.

An important characteristic is the reversibility of the amplidyne armature voltage, whereby the same degree of forcing is possible in both directions—that is, increasing and decreasing excitation. The amplidyne exciter is driven either by a d.c. motor, supplied from the constant-voltage pilot exciter when one is available, or by an a.c. squirrel-cage motor supplied from the available low-tension a.c. station supply; this is a flexible arrangement and enables the regulator to be applied readily to both new and existing installations. Facilities such as positive-phase sequence control and compounding for parallel operation, which are common to most voltage regulators, are provided as required. The changeover from "Hand" to "Auto" control and vice versa can be made smoothly without disturbance to the system. Protection is provided which automatically returns the generator to "Hand" control in the event of a regulator failure. The various controls, such as voltage adjusting rheostat and "Hand"/"Auto" control switch can be mounted either on the regulator cubicle or remote from it as required.

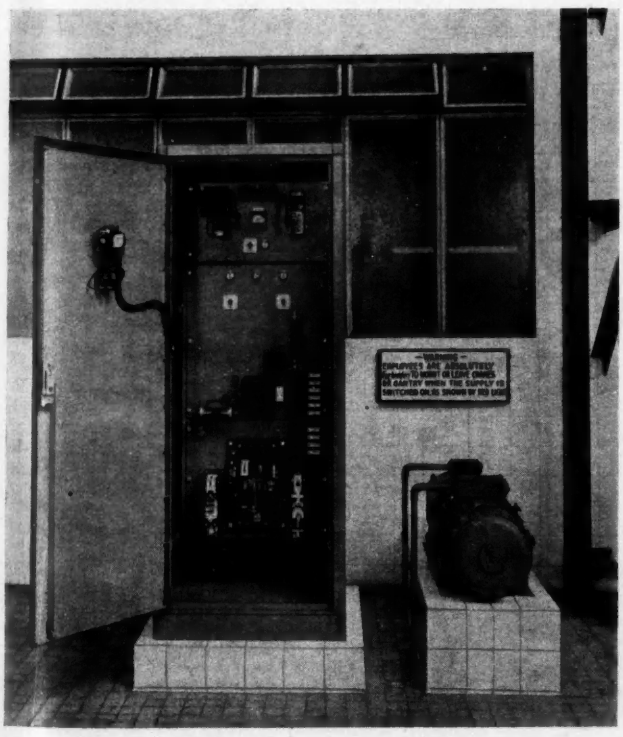


Fig. 3—"Magnestat" voltage regulator as used to control the voltage of a 30MW turbo-alternator—B.T.H.

One of the switchgear exhibits on this stand will be a three-phase automatic circuit recloser designed for improving continuity of supply on rural transmission lines up to 11kV. Its function is to open instantaneously on a fault and to reclose automatically, with the aim of clearing the fault and restoring the supply before the fuse (which is co-ordinated with it) can blow. It therefore prevents the interruption in supply that would be caused (if no auto-recloser were installed) by the blowing of the fuse and the time required for renewal.

The usefulness of the automatic recloser may be judged by recalling the observation that about 80 per cent of the faults on overhead lines, attributable to lightning, twigs or birds, are temporary and generally are cleared as soon as the line is re-energised. It is estimated that another 5 per cent of the faults can be cleared by a second operation of the recloser. To allow for persistent faults the recloser is designed to perform four consecutive opening operations and then (if the fault is still not cleared) to lock open. The first two opening operations are instantaneous and the next two have an inverse time characteristic, so that the recloser can be co-ordinated with the 11kV fuses.

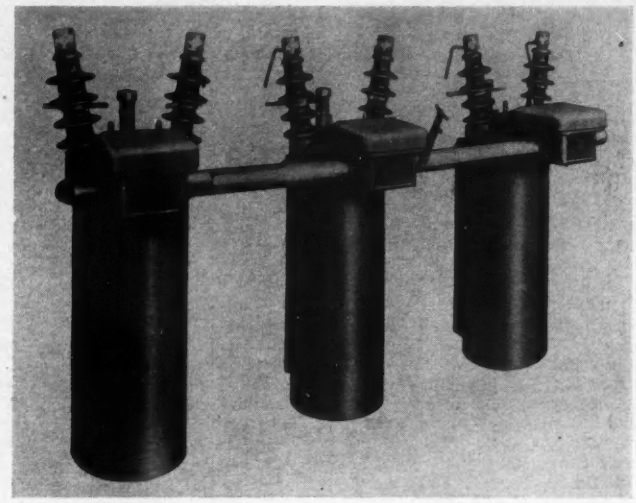


Fig. 4—Automatic three-phase circuit recloser for rural transmission lines—B.T.H.

The recloser (Fig. 4) is a single-pole, dead tank equipment and its contacts are normally held closed by springs. When a fault occurs the fault current passing through a series-connected solenoid coil causes the switch to open automatically, the minimum current needed to do this being twice the current rating of the coil.

We may recall* that last September the Midlands Electricity Board conducted a series of demonstrations with automatic circuit reclosers at its Upton Warren Testing Station.

(To be continued)

Technical Report

Fatigue Tests on Rolled Alloy Steels Made in Electric and Open-Hearth Furnaces. By P. H. Frith, A.Met., F.I.M. Iron and Steel Institute Special Report No. 50. London: British Iron and Steel Research Association, 11, Park Lane, W.1. Price 25s.—This report gives the detailed results of more than thirteen years' study of the fatigue problem in relation to high-quality steels. This work was originally instituted by the Inclusions Sub-Committee of the Iron and Steel Institute, to investigate the practicability of measuring the standard of cleanness of aircraft steels through a numerical count, especially by the so-called "Fox Inclusion Count." It eventually became the responsibility of the Fatigue and Inclusion Committee of B.I.S.R.A.'s Metallurgy (General) Division.

The studies of steels heat-treated from 60 to 110 tons per square inch U.T.S. show that inclusions of the size and type present appeared to have no detrimental effect on the properties of steels with an ultimate tensile strength of 60 tons per square inch. Observations suggest that extraneous inclusions in more massive form would probably be detrimental. The effects of the inclusions present grew progressively more marked in steels with a greater U.T.S., the type of inclusion producing the greatest decrease in fatigue resistance appearing to be undeformed spherical silicates. It was found, for example, that these inclusions reduced the longitudinal fatigue limit of basic electro-arc normal procedure steels, heat-treated to 110 tons per square inch U.T.S. by at least 17 per cent.

The report also includes the results of similar studies of chromium-carbon steels heat-treated to a hardness of 750 D.P.N. In addition to conventional metallographic methods, the micro-radiographic technique was also employed throughout the investigation.

* The Engineer, October 29, 1954, page 606.

Worsted Yarn Factory at Peterlee

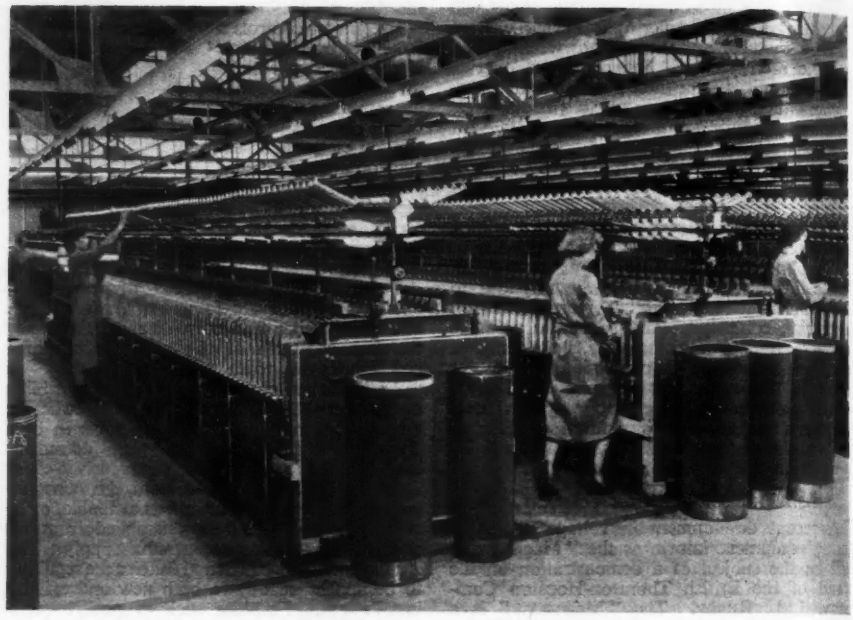
THE first factory on the Peterlee Trading Estate in County Durham has been built to the special requirements of Jeremiah Ambler, Ltd., the Bradford firm of worsted spinners. The new factory, together with offices and ancillary buildings, covers an area of some 70,000 square feet, and it was built by Bovis, Ltd., to the order of the North Eastern Trading Estates, Ltd.

In preparing the designs for the factory particular problems were involved, as it is situated over an area in which there are coal workings and where coal will be extracted for some years to come. The possibility of subsidence in the future had, therefore, to be taken into account, and this problem was studied by a working party consisting of engineers to the Peterlee Development Corporation and the National Coal Board. The Board subsequently agreed to accept responsibility for compensation for certain damage which might take place to the factory structure due to subsidence after mining operations had ceased, providing the recommendations of the working party were implemented. The siting of the building was agreed with the working party, which recommended that the building site should have its longest axis parallel to the contours of the land.

Two methods of building construction were employed for the factory, one corner of which can be seen in an illustration on this page. The main factory production area is of steel-frame construction to provide the maximum clear floor space. Brick load bearing walls with 11in cavity were used in the construction of the office block, ancillary buildings, loading and unloading bays, electric substation and the garage and boiler-house immediately adjoining the production building. These brick sections of the factory are on separate foundations and movement joints between them and the main production building allow vertical and horizontal movement, similar joints also being provided between the office block and ancillary accommodation. Where brick buildings are more than 75ft long, vertical expansion joints are incorporated in their structure. Movement between the brick load-bearing structures and the steel frame factory has been allowed for. Pipes from the service buildings to the factory pass through brick panels surrounding the doorways giving access between the two kinds of building. These door panels are connected to—and will move with—the brick load-bearing structures and not with the steel-frame factory.

The main factory covers an area of 57,760 square feet, and is a steel-frame building 380ft long by 156ft wide, in two spans with a centre row of stanchions. In anticipation of the effects of subsidence, the external stanchions of the building are seated on rollers allowing a maximum movement, in the direction across the width of the factory, of 3in each way. The centre stanchions are seated on fixed rocker joints. The double-skinned factory walls have an internal wall of 2in "Stramit" boarding, covered with ¼in hardboard. This boarding is in 11ft lengths to cover all the bracing steelwork, and the external covering is in 20 gauge aluminium sheeting where not covered by the adjoining brick buildings. All the buildings are roofed with "Bitumetal" aluminium decking, and particular attention has been given to ensure effective insulation throughout as humidity and temperature conditions have to be closely controlled on the factory floor.

Good natural lighting is provided by glazing above 11ft 6in from floor level and extending round the factory except at the extreme ends for the extent of the loading and unloading bays. Additional lighting is provided by high-level monitors, two to each span and extending the full length of the factory. Eighteen separate units provide humidified air to the main production floor through roof level trunking extending across the full width of the building, and this equipment is designed to maintain a humidity between 65 and 75 per cent at a temperature of 65 deg. Fah.



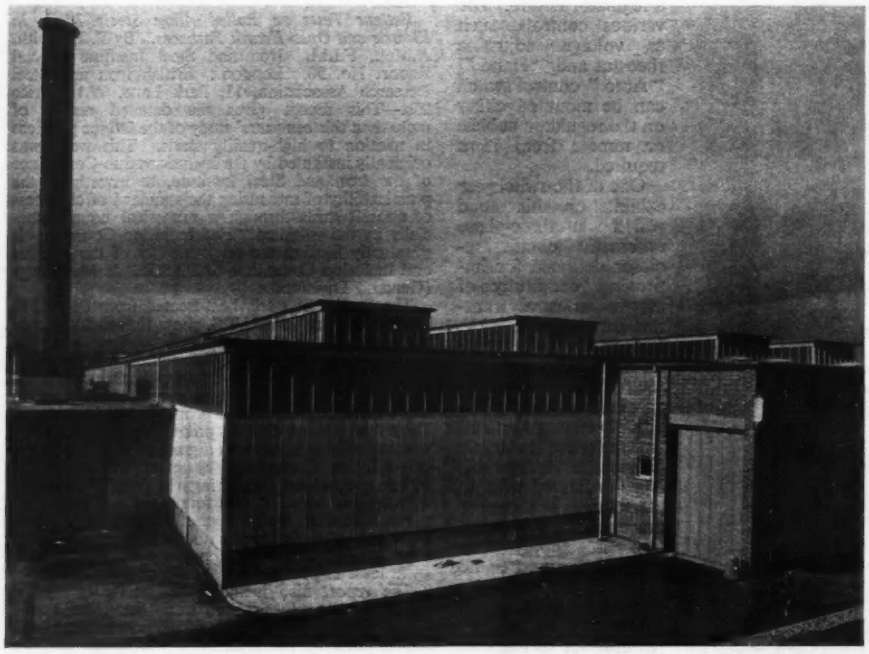
Twisting and doubling machine section of the factory

The factory floor is hardened granolithic concrete laid *in situ* with the sub-floor, and in view of the anticipated subsidence the floor has been divided into sections in such a way that the machines do not straddle the joints. The sections are provided with movement joints and coupled together by high-tensile steel dowels, which are locked in the slab at one end and left free to move in a slot in the adjacent slab. These movement joints are covered with tiles placed on bituminous sand and set flush with the floor. In the event of excessive movement between slabs these tiles will fracture and they can be easily replaced.

The loading and unloading bays of load-bearing brick construction have the platforms set at lorry deck height and are fitted with external doors. As the factory is air conditioned with a positive pressure, no great air change is anticipated when inside doors are opened providing the outer doors of the bays are shut.

Two treble-pass boilers capable of evaporating 2300 lb of water an hour supply steam to the heating batteries of the air-conditioning units in the factory, and to convectors in the garage and loading and unloading bays.

When Jeremiah Ambler, Ltd., first considered setting up this new factory investigations were made in this country and abroad into the various methods and different machines before deciding upon the equipment which should be installed. It was eventually considered that yarn produced by the American long draft system would give the best results at the lowest costs, provided that the machinery could be utilised to its maximum



Textile factory at Peterlee having a steel-framed production building with offices and ancillary buildings of brick construction

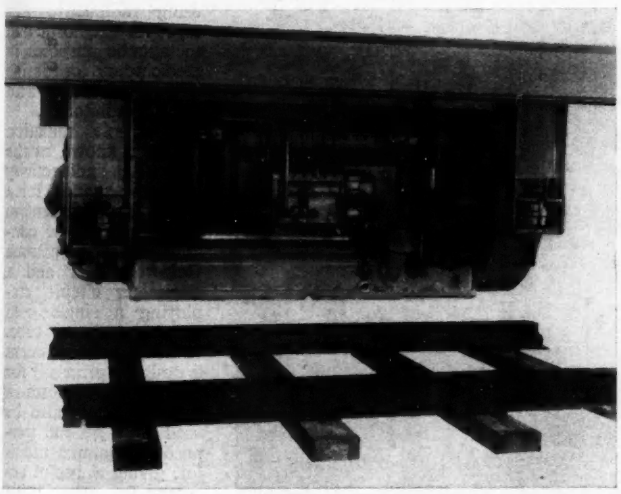
capacity. The factory has therefore been equipped with a selection of British and American-built machines designed to reduce to a minimum the number of operations required, give a high output per operator and occupy the smallest reasonable floor space.

In the first of the series of operations in making the wool yarn wool fibres are drawn out and reduced into an untwisted sliver on a group of "Raper Autoleveller" machines made by Prince Smith and Stells, Ltd. These machines produce a roving free from irregularities ready for spinning. The roving is transferred in cans to spinning machines where it is reduced to yarn at high speed and wound on bobbins, ready for final twisting and doubling on the machines shown in our second illustration. In the final operation the yarn is wound on to a cone or into a hank, depending upon customer's requirements. At present about half of the machines which will eventually be installed have been laid down on the factory floor. The spinning machines and the doubling and twisting machines installed were supplied by the Saco-Lowell Company of the United States. We are informed that plans have been made to secure the additional machines required from British manufacturers.

As it was intended from the outset to recruit all labour from the surrounding area the firm set up a small pilot factory in West Hartlepool for training girls on the new machines. As a result of this scheme sufficient skilled operatives were available to provide a double shift for the machines as they were installed in the new factory.

Horizontal Oil Engine for Railway Traction

FOR a considerable number of years Davey, Paxman and Co., Ltd., has been engaged in the construction of high-speed oil engines, for railway traction, having cylinders of 7in diameter by 7½in stroke, and both Ricardo and direct injection four valve heads. These engines were of vee form with cylinder banks at an included angle of 60 deg. and developed a traction rating ranging from 133 b.h.p. to 833 b.h.p. The company has now added another design to its range of engines with its development of a single bank horizontal unit intended specifically for powering railcars and multi-car trains. This unit, model "ZHL," has an output of 300 b.h.p. when naturally aspirated and 450 b.h.p. when pressure charged with a Napier turbo-blower group. Despite the considerable power output, which is high for a railcar flat engine, the new unit fits comfortably below the car floor in vehicles built to the British loading gauge and even those built to a smaller gauge, such as cars restricted to 8ft 6in in width on the 3ft 6in rail gauge of New Zealand. This is possible since the engine has an overall length of 6ft 11in naturally aspirated or 8ft 5in pressure charged, a maximum width of 5ft 2½in and a maximum height of 36in.

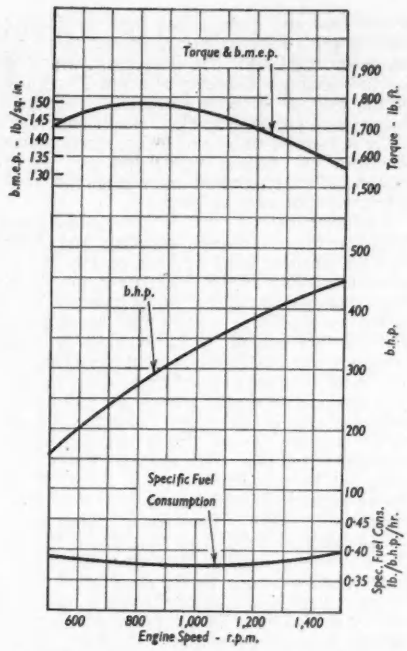


Paxman "ZHL" single-bank horizontal engine of 300 b.h.p. at 1500 r.p.m. mounted beneath railcar underframe

The new engine incorporates the proved design elements of the two existing series of Paxman vee engines, in particular, the use of aluminium alloy castings for the crankcase, cylinder block and cylinder heads. Considerable experience has been gained during recent years in the constructional use and performance of both cast and welded aluminium alloy engine frames and other stressed parts so that it has been found possible to produce a rigid structure free from general or local deformations. Thus, by a combination of the use of light alloy material and careful design a robust engine has been developed with a dry weight of 5100 lb or 17 lb per b.h.p. for the naturally aspirated model, and 13 lb per b.h.p. for the pressure charged version. Accessibility is the keynote of the design so that all parts which may need attention between overhauls, such as fuel pumps, valve gear and tappets, filters and timing gears, can be adjusted at the sides from rail level. Also the engine is mounted so that after disconnecting the drive, it can be lowered and removed sideways.

Our photograph indicates the general appearance of the engine and serves to illustrate the rail clearance. To suit the underfloor location and the general methods of support from a railcar underframe a four-point mounting, consisting of vibro-insulators manufactured by the British Tyre and Rubber Company, Ltd., has been adopted. The engine has six cylinders of 7in diameter by 7½in stroke and when naturally aspirated develops 300 b.h.p. at 1500 r.p.m. with a b.m.e.p. of 88½ lb per square inch. When pressure charged the corresponding performance figures are 450 b.h.p. at 1500 r.p.m. and a b.m.e.p. of 133 lb per square inch. We reproduce herewith the performance curves of the "6ZHL" naturally aspirated engine, and the "6ZHLX" pressure charged engine, from which it can be noted that the fuel consumption is 0·40 lb per b.h.p. per hour for both engines.

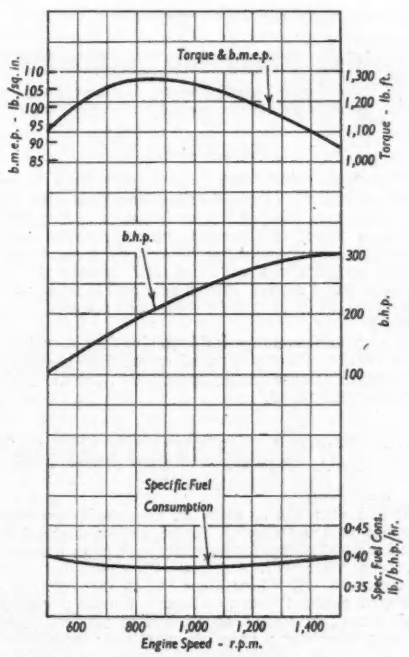
High strength corrosion-resisting aluminium alloy has been used for the single piece crankcase and cylinder block casting in which strong cross pieces carry the seven main bearings of underslung pattern. To take the side thrust away from the studs the deep forged aluminium alloy bearing caps are fitted closely into the frame structure. A large capacity finned sump, also an aluminium alloy casting, closes the bottom of the structure while two large pressed aluminium covers in the top surface give ready access to the engine when it is on the bench. In the cylinder bores are replaceable hardened and tempered cast iron liners surrounded by an ample cooling water space. The cylinder heads, cast in blocks of three, carry the valve rocker gear, which is force lubricated from the main system, and the rocker arms pivot on spindles carried in cast aluminium brackets. Easily removable covers are provided to permit adjustment of tappet clearance, this being done by



"6ZHLX" engine. Performance with fuel bar stop set to give 350 b.h.p. at 1500 r.p.m. (1 hr rating)

means of screw pattern adjusters in the valve actuating rockers and bridges. Four large diameter valves are fitted in each cylinder head and particular attention has been paid to the cooling of the aluminium bronze seats, while the ports are shaped to give a smooth, eddy-free flow to the air and exhaust gases. A single gear-driven camshaft, located beneath the cylinders, has integral cams which run in an oil bath and operate cam followers of roller design to actuate push rods resting in spherical seatings in the cam followers.

The cast aluminium alloy piston has a central combustion chamber machined out of the crown, three compression rings and two stepped oil control rings, one of which is below the fully floating, case-hardened gudgeon pin of 5 per cent nickel steel. Heat-treated carbon steel "I" section stampings are used for the connecting-rods, the big end being split at an angle to facilitate removal of the cap, bearing and rod. Glacier steel shell bearings lined with



"6ZHL" engine. Performance with fuel bar set to give 88·5lb b.m.e.p. (300 b.h.p.) at 1500 r.p.m.

copper-lead and given a lead flash are fitted at the big end, while at the small end there is a silicon-bronze bush. The crankshaft, which has journals having a diameter of about 70 per cent of the cylinder bore, is carried in seven main bearings of copper-lead-lined steel shells, those at the centre and ends being longer than standard to give a low specific bearing pressure. At the free end of the crankshaft and outside the crankcase a vibration damper is fitted.

Fuel injection is by a C.A.V. monobloc pump having a totally enclosed camshaft and driven through a cardan shaft by gears on the free end of the crankshaft and an adequate supply of fuel under pressure to the fuel pump gallery is maintained by a plunger pattern fuel boost pump. The oil fuel system, which includes a Vokes filter, is located externally so that the lubricating oil cannot be contaminated by any fuel leakage. Two engine-driven gear pumps are mounted at the front end of the engine, and the pressure pump supplies oil to the lubrication system through a full-flow felt element Vokes filter protected by a safety valve set at 80 lb per square inch and of sufficient capacity to ensure a low-pressure drop. The second pump passes low-pressure oil, at 18 lb per square inch, through the oil-cooling radiator and then through an Auto-Klean strainer. By the use of dual pumps in the system the radiator section is protected from the high internal oil pressure associated with single pump circulation. The high-pressure oil is led direct to the main gallery, which has a 50 lb per square inch pressure release valve. There is a constant flow of oil to the camshaft, while the rocker receives an intermittent supply of oil at full pressure via the camshaft.

A gear-driven centrifugal pump, having a bronze impeller on a stainless steel shaft running in plain bush journal bearings and housed in a cast iron casing, circulates the cooling water. From the pump delivery pipe a flexible connection leads the water direct to the underside of the engine. The water manifold is cast integrally with the main crankcase and connects with the outlets from the cylinder heads. A by-pass valve, thermostatically controlled, is incorporated in the jacket water system and contains two bellows-operated valve units which provide a temperature control ranging from 150 deg. to 160 deg. Fah. Electrical starting is provided and there is a C.A.V. 7in dynamo located beneath the engine in a space behind the starter motor. Other equipment, depending upon requirements, is provided such as a C.A.V. mechanical or servo governor engine control and an over-speed trip mechanism to shut down the engine in the event of excessive speed.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

SCREWDRIVERS

No. 2559 : 1955. Price 4s. Apart from being another in the list of specifications for a large selection of hand tools, this publication is one of four which, between them, will present the requirements for good quality screwdrivers of various basic types. Other specifications will deal with ratchet screwdrivers, spiral ratchet screwdrivers and those screwdrivers and bits designed for use with recessed head screws.

It was not found practicable to give the dimensions and details of every type of screwdriver available but those included in this specification are the ones very generally used.

FORGED STEEL PIPE FITTINGS, SCREWED WITH A.P.I. THREAD FOR THE PETROLEUM INDUSTRY

No. 2561 : 1955. Price 3s. 6d. This standard applies to the following forged carbon and alloy steel screwed fittings for assembly with pipes screwed in accordance with American Petroleum Institute Standard 5—L, "Line Pipe": 45 deg. elbows; 90 deg. elbows; tees; crosses; laterals; caps; bull plugs; hexagonal, square and round head pipe plugs; couplings; reducing couplings; hexagonal head bushings. The range of sizes is from ¼in to 4in and 6in and the range of ratings from 600 lb to 1500 lb per square inch within plot limits. Dimensions, tolerances, materials and marking are specified.

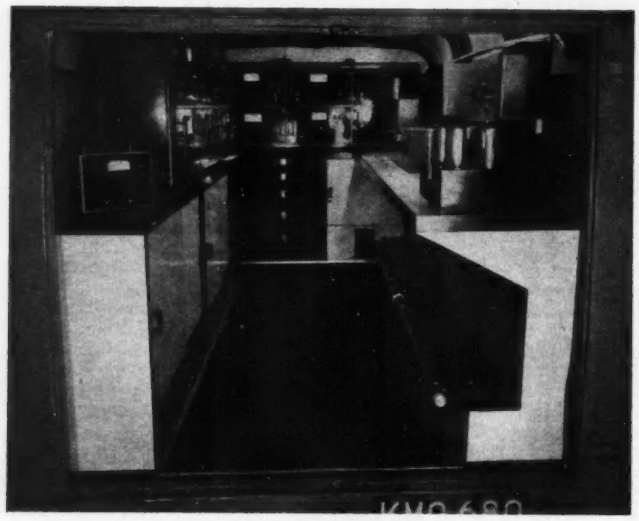
Mobile Laboratory for Demonstrating Nuclear Instruments

A MOBILE laboratory equipped to demonstrate a wide variety of instruments used in nuclear research and technology was demonstrated in London recently by Isotope Developments, Ltd., Aldermaston Wharf, Near Reading, Berks. This company was founded in 1950 to commercialise the peaceful uses of radioactive isotopes. Since then the firm has developed a number of standard instruments for industrial use, with particular reference to improved production control, and a range of laboratory instruments to cover the needs of nuclear physics research and the teaching of the principles of radioactivity and radio chemistry. The company also develops and makes specialised products to the requirements of the Atomic Energy Authority. Lastly, the company provides a consultancy service on radioactive tracer techniques and is engaged in the development of highly specialised instruments for research and industry.

To enable such instruments to be demonstrated to scientists and technicians in the seats of learning, hospitals and industrial centres, the company has put on the road a vehicle known as the "I.D.L. Mobile Unit."

Among the guests who were present at the recent demonstration of this unit was the Right Hon. Viscount Waverley, who spoke of the growing need for various means of informing non-scientific industrialists and engineers of the peaceful uses of atomic energy and, in particular, of radioactive isotopes. To illustrate the variety of applications he mentioned the recent use of a new isotope, radioactive scandium in work connected with coastal erosion and tidal movements.

The mobile unit, which was supplied by British Films, Ltd., 260, Balham High Road, London, S.W.17, consists of a Fordson 2-ton chassis, powered by a Ford "V8" engine and fitted with a standard Fordson 2-ton body insulated throughout with 2in of bitumen bonded "Fibreglass" to provide thermal and noise insulation. The inside of the body (as illustrated) is a single compartment equipped with benches panelled in "Formica" and arranged to carry an assortment of instruments and equipment, some of which are described below.



Interior of truck equipped to demonstrate industrial and laboratory instruments made by Isotope Developments, Ltd.

A Martin-Harper power take-off assembly is fitted to the engine gearbox to drive a self-regulating alternator rated at 3kVA, 230V, 50 c/s, 1500 r.p.m., and made by the Lancashire Dynamo and Crypto, Ltd. A Weyburn governor is fitted to the engine to keep the speed constant at 1100 r.p.m. when generating. Cables and sockets are provided so that, if required, power can be obtained from the public supply mains. Alternatively power can be fed from the generating set into a building where there is no mains supply available.

Among the laboratory instruments carried in the truck is a "532" e.h.t. supply unit which is designed to provide a stable source of high voltage for the operation of Geiger-Müller tubes, ionisation chambers and proportional and scintillation counters. There is also a "550" rate-meter—a general-purpose instrument capable of covering a wide range of counting rates with an accuracy of ±1 per cent of full-scale reading. It provides aural and visual indication of the count rate. For use in conjunction with this rate-meter there is a "649" universal probe unit, consisting of a Geiger-Müller tube mounted on a cast alloy handle which contains a built-in cathode-follower stage; the cathode follower components are contained in a synthetic resin capsule to ensure that the probe can withstand considerable shock and vibration in use. For physical, medical and biological work in research and in industry, a "500" scaler is installed to measure counting rates up to 80,000 counts per minute. The track also carries a "501" pre-scaler, designed primarily for use in cascade with the "500" scaler, from which it takes its power supplies. The two instruments form a combination with a very short resolving time and a high maximum counting rate. They are thus suitable for use with fast nuclear detectors, such as scintillation counters, ionisation chambers and proportional counters.

Another instrument, the "653" scintillation counter head, is intended for use with a variety of phosphors in work connected with alpha, beta and gamma rays, protons, neutrons and X-rays. It has been designed for research measurements (for example, gamma ray spectrometry) when using radioactive isotopes for diagnostic and therapeutic purposes in medicine and for routine investigations and general monitoring.

A simple radiation monitor, known as the "552" radioactivity meter, is provided. It is a simple and inexpensive radiation monitor consisting of a beta/gamma Geiger counter and a rate-meter circuit employing a single cold cathode trigger tube. Although the instrument is designed primarily for educational purposes in schools, it can also be used as a general purpose beta/gamma monitor, giving a useful accuracy for quantitative measurements.

Among the industrial instruments carried in the truck is a "120" beta gauge based on the absorption, by the material being gauged, of the emission from a radioactive source, the intensity of the radiations after passing through the material, being a measurement of the weight and thickness. A measuring head detects the radiations thus transmitted through the sheet material and, by conversion to electrical energy, the amount (and in consequence, the weight or thickness of the material) is indicated upon a meter. There is also a "210" package monitor designed to check on a conveyor line the packaging of such products (in solid, liquid or paste form) as drugs, soap powders, foodstuffs or rifle cartridges, either before or after the containers have been sealed and are ready for dispatch.

Finally, the laboratory truck contains an "850" ionisation anemometer, a robust portable instrument without moving parts, for the measurement of very low speed air currents ranging from 10ft to 300ft per minute.

Investigation into the Failure of Two 100MW Turbo-Generators*

No. IV—(*Concluded from page 298, March 4th*)

By SIR CLAUDE GIBB, C.B.E., D.Sc., M.E., F.R.S.†

This paper describes investigations into the failure of two generators, each of 100MW capacity, installed in the Richard L. Hearn Generating Station at Toronto of The Hydro-Electric Power Commission of Ontario. The author details some general considerations affecting the design of alternator rotors, the selection of materials used, past troubles which had to be avoided, reasons for certain features incorporated in the original design and modified as the result of the failures, and safeguards introduced into current practice to avoid the possibility of a repetition of the failures.

Design Changes

SHORTLY after the 1939–45 war, it was realised that with the rapid growth of turbo-generator size, stress considerations would preclude the use of ventilating holes in end bells, and an improvement in rotor ventilation was essential to permit their elimination. A form of ventilation with cooling air in direct contact with rotor copper had been considered and rejected because of the danger of dust, carbon, or oil vapour being drawn in and by reduction of leakage path lead to insulation breakdown. With hydrogen cooling such potential dangers do not exist and development of that design was pursued vigorously and first put into commercial service in 1952 on a 60MW, 3000 r.p.m. unit. Direct hydrogen cooling is a great success and has reduced rotor temperature rise far more than would have been the increase due to the elimination of end bell ventilating holes. The 60-cycle, four-pole rotor for No. 3 Toronto unit had already been completed with the new design of direct-cooled windings and was ready for dispatch when the failure occurred on No. 1 unit. Dispatch was delayed until some detailed information was received from the site, but it was necessary to make an early decision as to action to be taken, so that both No. 3 and No. 4 units, which had been kept out of service after the failure of No. 2 set, could be recommissioned with absolute safety at the earliest possible date.

At that time, it was not by any means certain that it was the end bells which had failed first, but they were the obvious things to suspect since they were the most highly stressed components. If it were end bells, then material or the effect of ventilating holes would be the most likely causes of the failure.

It was decided, therefore, to replace the end bells with a well-known chrome-molybdenum alloy which would give the required physical properties by simple heat-treatment, but would be magnetic. Since direct cooling already existed on No. 3 rotor, ventilating holes were not required and would not be used. No. 4 rotor was returned to England, remachined for the direct-cooling subslots, and was then rewound and fitted with magnetic end bells without ventilating holes. No. 3 unit was returned to service on August 31, 1954, and No. 4 unit on September 15, 1954.

A complete new 100MW generator for No. 2 set was built and tested in less than seven months and is expected to be in service in ten months from the date of failure.

In the light of the subsequent investigations, the decision taken to change end bell material for the Toronto generators and omit ventilating holes was a sound one.

Changes which had been made in non-magnetic end bell forging technique prior to the failures in April, 1954, have, however, been demonstrated by the investigations to lead to a reduction in residual stresses, and no hesitation would now be felt in fitting non-magnetic end bells to machines similar to those at Toronto provided that direct-cooling of the rotor were adopted with the elimination of ventilating holes.

Every end bell, after machining, is now hydraulically tested to a mean hoop stress of 35 tons per square inch and is then radiographed, supersonically tested, and crack-detected with the penetrant dye method. It is important to note, however, that had these additional tests been current practice at the time of manufacturing the Toronto end bells, they would all have been passed without doubt.

Metallurgical and Mechanical Properties

Metallurgical and mechanical tests carried out on the two Toronto end bells that failed in service, and others that were cracked or fractured in pressure tests, gave little indication that they differed substantially in regard to composition or grain size from acceptable standards based on previous experience. It is to be noted, however [Appendix I of the paper] that the relations between the elongation and reduction in area on the one hand, and the yield point on the other, shown by the tests carried out on bells after failure, are not as good as those (particularly No. 1 exciter end bell) in general obtained in acceptance tests. As these are the only end bells for which numbers of tests have been carried out on the body, it cannot be stated whether this feature is peculiar to these bells or common to all bells. It is probably common to all bells.

In the following table an attempt is made to compare the various bells on the basis of the ratio of the elongation and reduction in area to the yield point :—

End bell	Relationship of elongation to yield point	Relationship of reduction in area to yield point
No. 1, exciter end	Low	Low
No. 2, exciter end	Medium	Low
No. 2, turbine end	High	Medium
No. 4, exciter end	Medium	Low

Possible Effects of Operating Conditions

After an all-night shut down, it seems possible that on starting up with the hydrogen cold there may be a temperature difference of 20 deg. to 25 deg. Cent. between the rotor body and the end bell owing to the rapid cooling of the latter. Under such conditions the shrink stress and the effective hoop stress (algebraic sum of the hoop stress and the circumferential bending stress) will increase at running speed [as is shown in comparing Fig. 20(*a*) and (*b*) in Appendix II of the paper].

At the same time, the Izod value for the material which appears from Table VII to fall more or less proportionately with decrease in temperature, will decrease, although not to a disturbingly low level. The chief interest in this assumed condition springs from the cyclic behaviour of the end bell under which failure was induced at the relatively low mean hoop stress of 27·6 tons per square inch in relatively few reversals. One cannot, therefore, lightly discount the possible effects of the particular circumstances of operation for the bells under consideration.

Effect of Holes

From all the available evidence it seems clear that failure of all the bells that have failed in service or in test springs from the holes. These are undoubtedly severely work-hardened and undoubtedly give rise to stress concentrations of a high order. The inability of the metal immediately adjacent to the holes to spread the high stress by deformation is clearly shown by the increasing ductility apparent as the crack proceeds away from the hole. The holes vary in surface finish, but without question the high hardness gives rise to increased notch sensitivity. The fact that in all the bells fractured in service, or in tests, varying numbers of holes other than those through which the fracture took place were cracked, indicates a general rather than a local onset of the failure condition. Without doubt, therefore, in the light of the evidence, holes have a substantial effect in weakening the end bell. The fact that surface hardness often is a maximum at the mid-depth of the hole, and that stress also is a maximum at mid-thickness, is important, since then at the area of maximum stress there can be the minimum of plastic flow and therefore a maximum of stress concentration. It is clear that cracks can then be initiated at the mid-depth surface of holes under relatively few repetitions of a range of stress, the upper limit of which does not greatly exceed that to which they might well be subjected in service, although the range under the conditions of the tests was considerably greater than that obtained under operating conditions. That they are not under all conditions a predominant cause of failure can perhaps best be indicated by the behaviour of a 7500kW, 3600 r.p.m., turbo-generator in Venezuela, which, in September, 1949, ran to an excessive overspeed. Both of the rotor fans burst, completely wrecking the stator end windings, but no mechanical distortion could be detected on either the rotor forging or on the rotor end bells. The rotor end windings were ventilated by means of holes in the end bells. The overspeed was caused by continuous operation with the governor set at its top limit ; boiler deposits formed on the neck of the gland of the relay valve, which jammed open and the runaway valve failed to close by about ¼in. The stator and rotor were returned to England for repair and examination and were, in fact, returned to site and recommissioned early in the following December.

Unfortunately, the exact speed attained was not observed, but, since in addition to the bursting of two fans subsequent examination of the rotor showed that the bronze slot wedges were slightly deformed in shear, it became possible to estimate the speed attained.

The rotor fans were of the centrifugal type and the most highly stressed part was the front shroud in which the normal running stress was 11·45 tons per square inch. The ultimate tensile strength of the material used was 40–45 tons per square inch, so that the speed corresponding to the lower figure would be 6730 r.p.m. Both of the rotor fans burst and it is not known, of course, how much the speed continued to rise after this happened.

The wedges closing the rotor slot were of bronze having a nominal yield point of 16 tons per square inch, and a normal running shear stress of 2·58 tons per square inch. Tests on this material indicated that yield might be expected to commence at a figure as low as 9 tons per square inch, so that on this basis the maximum speed attained would be expected to be 6700 r.p.m.

The end bells were of non-magnetic steel and the tensile test figures for the yield and ultimate were 57 and 63·6 tons per square inch respectively. The hoop stress in the end bell at 3600 r.p.m. was 16 tons per square inch, so that at an overspeed of 6700 r.p.m. the bell stress must have been 56·5 tons per square inch, which is very close to the yield point of 57 tons per square inch. The holes in the end bell did not appear to exercise any appreciable weakening effect and it is probable that with a bell of this thickness the amount of locked-up stress was small.

Disposition of Holes.—The disposition of the holes has evidently an important effect in determining the behaviour of end bells subjected to stress. In the three exciter end bells that fractured either in service or in test the fracture passed through three similarly disposed holes and all the cracks found in the 37in diameter bells were in similar diagonal rows of holes. It is quite probable that bells of the Toronto type and of the 37in diameter type may behave differently in service simply because of the different disposition of the holes.

Residual Stress.—Sufficient evidence is available to show the variability and unpredictability of locked-up stress in non-magnetic end bells. The effect of holes on its magnitude and distribution is likewise unpredictable.

It is clear (Table IV) that almost irrespective of size or yield point the effect of holes is to limit the mean applied hoop stress at failure to the order of some 40 tons per square inch. There is one exception—No. 2 Toronto turbine end bell which failed at an applied hoop stress of some 35 tons per square inch. It is obviously difficult to assess the extent to which locked-up stress might be responsible for this, but it may be of some significance that, as mentioned previously, the end bells for Nos. 1 and 2 machines were not made in a manner similar to those used for Nos. 3 and 4 machines, or for the 37in diameter end bells used for comparative tests.

Little relief of residual stress could be expected in the neighbourhood of the holes at any reasonable applied stress level, having regard to the hardness obtaining there and, owing to the stress concentration factor associated with the holes,

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any appreciable residual stress could have a pronounced effect on behaviour.

Shock.—It must always be a matter of conjecture as to what extent the failure of the first machine was directly responsible for the failure of the second. In general, the properties of the end bell material for the latter were better than those of the former, and the possibility of inertia shock initiating a crack in the second set cannot be discounted.

Brittle Fracture

The failures that occurred in the exciter end bells of Nos. 1 and 2 units—that is, those that failed completely in service, and also the failure that occurred under hydraulic pressure test on No. 4 exciter end bell, had a close resemblance to the "brittle fractures" that have occurred from time to time in welded ships, high-pressure gas mains, fluid storage reservoirs and other welded steel structures. These failures have been characterised by high general stress and the presence of a welding fault or other defect, for example, a surface crack or a constructional feature which introduces a concentration of stress, especially if aided by a localised deficiency of ductility, may start a local or restricted crack which, entering the region under general stress, sets off therein an extensive crack of great suddenness, and probably with catastrophic consequences. The conditions of a high general stress, the presence of a stress concentration feature and local deficiency in ductility are those which apply to the end bells. The failures would thus begin at points of stress concentration which might be cracks formed at the surface of holes and they propagate very rapidly, as is known to have occurred in the end bell of No. 4 exciter end that failed under hydraulic pressure, and is assumed to have been the case in the bells that failed in service. Furthermore, the surface of these fractures showed chevron-like markings which enabled the point at which the failure began to be identified. The only respect in which the failures in the end bells differed from the characteristic mild steel brittle fractures was that they were intercrystalline and not transcrystalline or cleavage. This may be accounted for by the fact that in the end bells the material was an austenitic steel in which fracture normally is intercrystalline, whereas in mild steel fracture is normally transcrystalline.

A large number of investigations have been carried out on brittle fracture in order to ascertain the conditions under which it occurs, and many factors have been suggested as contributing to it. Of these, the main factors seem to be the presence of a multi-axial stress system, in so far as the stress system may limit ductility and thereby promote cracking, a notch of some kind, or low temperature and low notch toughness in the steel. These factors apply particularly where a brittle crack is initiated. After initiation a brittle crack may spread extensively where the general stress system may be only simple tension; for example, the circumferential tension at the shell of a cylindrical storage reservoir, the spreading crack itself carrying with it its own stress concentration feature and system of complex stresses as it travels.

Various combinations of these factors may cause brittle fracture. For example, if the notch is very sharp and the temperature very low, it may not be necessary for the steel to have a low impact toughness. Whereas, if the notch is sharp and the steel has a low impact toughness, it may not be necessary for the temperature to be low.

It is clear that, in addition to the fact that the fractures of the end bells had most of the characteristics of brittle fractures, the conditions of service conformed with the circumstances under which brittle fracture may occur. The hoop stress, shrink stress, thermal stress, and residual stress in the bells could, in combination give a resultant stress high enough to support the propagation of a brittle fracture in a material susceptible to this mode of failure if initiated by a feature of sufficient intensity, which is the significant and important fact of a brittle fracture, because working and design stresses usually exceed those able to support propagation. The steel has a relatively low impact toughness; at times the temperature of the bells was low and the holes and small cracks formed in them by repeated cycles of stress would provide the notches required to start brittle fracture.

With No. 4 exciter end bell the fracture under hydraulic pressure test was to all intents and purposes the same as those that occurred in service. In this test the stress system would be simpler than in service and the question of low temperature did not arise. This suggests that it is the notch effect and the properties of the steel that are the controlling factors.

With No. 1 unit, which failed shortly after going on to a light load following an overnight shut-down, at the time of failure chilling of the end bells would have occurred whilst the rotor remained hot. In consequence, the stress due to shrink at the rotor body had increased and the lower temperature of the end bell, together with the increase in shrink stress, may have produced the combination of conditions which triggered off a brittle fracture. No. 2 unit, however, failed after several hours on full load when end bell temperatures would be reasonably high and shrink stress would be a minimum. Hence, although the conditions generally considered to be associated with brittle fractures could be regarded as having been present in the failure of No. 1 unit, that does not appear to be the case with No. 2 unit. On the other hand, the hydraulic testing of No. 4 exciter end bell was carried out during warm weather at an atmospheric temperature of approximately 65 deg. Fah. and the end bell failed in a manner which could legitimately be termed a brittle fracture.

There is evidence that brittle fracture is more likely to occur in thick material than in thin, and at a low temperature. This may well account for the difference in behaviour between the Venezuela end bells which were much thinner than those at Toronto, and certainly were at a much higher temperature when the serious overspeed occurred without affecting the end bells. Further, the Venezuela end bells, being thinner, almost certainly would have lower residual stresses than those at Toronto.

The three Toronto end bells which failed with explosive violence were each from the exciter end. No metallurgical reason could be found why, in each instance, it was the exciter end which failed whilst the turbine end was quite unaffected and in perfect condition. There was, however, a minor difference between turbine and exciter end bells, in that at the exciter end the cross-over connections between coils would have blanked certain ventilating holes which, therefore, were not drilled. Thus there were twelve holes less in the exciter end bells than at the turbine end. The effect of the omission of these holes, which are shaded in Fig. 5 (*a*), each having the letter *A* after its number, was to induce a possible increase of stress not exceeding 1 ton per square inch at the hole where failure was initiated in the exciter end bells of Nos. 1, 2, and 4 units. This small increase of stress may well have been significant in locating the actual plane of fracture.

General

When the investigation of the relations between the properties of components, and the service conditions under which they operate, shows that the margin of safety is less than experience up to the time of failure would indicate, it is generally difficult—lacking a glaring reason for the failure—to ascribe it to a particular cause. Many variables, each in themselves not decisively significant, may combine to cause failure.

Previous experience and design by the same maker using end bells of similar material, drilled with ventilation holes, had been completely free from failure of the kind described by this paper. This circumstance, taken into account with the greater margin of safety which would be conferred by not drilling holes, will convey an idea of the greatly increased margin of safety introduced by the changes made as a consequence of the failures and referred to in the paper.

Conclusion

The broad canvas covered in the analysis has been drawn from a mass of intimate detail. Its inclusion in the body of the paper would, it was thought, rather cloud than clarify the picture, but in the hands of those competent to judge it may serve to throw some fresh light on the subject and so a representative cross-section has been included in Appendix I.

In matters of such widespread importance as the Toronto failures it is clearly the duty of all concerned to sift every tittle of evidence with meticulous care and to undertake and make public the results of every practicable investigation as to the cause of failure.

This paper is an endeavour to make the best possible use of the available material and to present the full results of the investigations and conclusions in a form readily understood by engineers.

The author wishes to make it clear that he is merely reporting the work of many metallurgists, engineers, and applied mathematicians. In particular, reference should be made to the investigations of Dr. Charles Sykes, F.R.S., and his colleagues and staff in the Brown-Firth Research Laboratories, and to the many at Heaton Works who worked such long hours over a long period endeavouring to obtain a definite conclusion to a very worrying disaster.

Finally, but by no means least, tribute is paid to Dr. Richard L. Hearn, Chief Engineer and General Manager of Ontario Hydro, who, with his colleagues and staff, at all times showed sympathy and great understanding and provided invaluable assistance to those making the investigations.

Igniter for Turbo-Jet Engines

A new design of a high-energy torch igniter has been developed by K.L.G. Sparking Plugs, Ltd. It was produced initially for the de Havilland "Ghost" engine, but the igniter can be applied to other gas turbine engines. It has been developed for use with the Dowty Spill Burner fuel system. Igniters normally consist of an ignition plug whose spark touches off the edge of the fuel spray from the main burner. Sometimes through a combination of circumstances the fuel is not ignited quickly, which may cause, on the ground, a "wet" start or, in the air, difficulty in relighting.

High-energy torch igniter showing on the left the igniter and on the right the auxiliary spray

Without altering the overall dimensions of its present igniter adaptor—which is bolted to the outer can and carries the igniter into the inner flame can—the company, in conjunction with the de Havilland Engine Company, has redesigned the unit so that alongside the igniter is a fuel atomiser. The centre of the fuel nozzle for this auxiliary spray is only 0·5in from the high-energy igniter electrode. During the starting cycle, fuel from the auxiliary spray ignites in a ball of flame which projects well down into the main fuel stream. In spite of its greater advantages, the height of the new igniter above the outer can is little greater than the previous installation.

Progress of the Tennessee Valley Authority

BY OUR AMERICAN EDITOR

WHEN the waters of the South Fork Holston River, impounded behind the new Fort Patrick Henry dam, began to turn two generators during the past year, the Tennessee Valley development reached a milestone of some significance : for the first time in twenty-one years T.V.A. had no dam under construction. But the demand for more electric power, particularly for purposes of national defence, continued to rise steadily. To meet it, new steam-electric generating capacity was being constructed at half a dozen sites along the waterways of the region, endeavouring to double the 1954 output of the T.V.A. power system in a little more than two years. These circumstances illustrate the fact that the Tennessee Valley region's need for power, and particularly the tremendous requirements of the U.S. Atomic Energy Commission and other defence plants, had several years ago passed the point where the hydro-electric resources of the region could meet the demand. The waters of the Tennessee River and its tributaries, although supporting one of the largest hydro-electric systems in the country, were insufficient to generate the needed power even with the development of the remaining dam sites. Thus, in 1954, for the first time, steam power generation exceeded hydro-electric generation.

Three major factors combined to bring about this change : (1) During the last war the power requirements of industries producing aluminium, chemicals and other essential war materials and of the initial atomic energy installation at Oak Ridge, Tennessee, had dictated an acceleration of the long-range river development plans of T.V.A. (2) After the war, a resurgence of non-defence economy took place. Rural electrification spread rapidly over the region, domestic use climbed sharply and new industry took root. (3) The "cold" war and the Korean conflict dictated a renewed development of power capacity for atomic energy installations. A strategic research centre for supersonic aircraft was established in the region, and critical metals and chemicals were being produced at new and expanded works. In the fiscal year 1954, T.V.A. generated nearly 30,000 million kWh of electricity. By 1956, with plants now under construction, about twice that much energy will be produced ; of the 60,000 million kWh to be generated, nearly half will be used by defence installations of the U.S. Federal Government—as much power as all of the generators of the Authority produced in 1954.

Construction Progress

In the past year, the Authority accelerated the construction of new generating capacity to meet the burgeoning demands of national defence projects and the growing economy of the region. The installed generating capacity of the integrated system was increased by 972·7MW during the year to a total of 6075MW. Most of the output of the new capacity was supplied immediately to national defence projects of the U.S. Federal Government, primarily the two large plants of the Atomic Energy Commission at Oak Ridge, Tennessee and Paducah, Kentucky, and the Arnold Engineering Development Centre of the U.S. Air Force in Middle Tennessee. Of the new generating capacity, T.V.A. added 787·5MW in six units at three of the six steam power stations that were under construction during the year and 158·5MW in five generating units at four of the Authority dams. Construction continued on an additional 3924·8MW, which will bring the installed capacity of the integrated system to 10,000MW in June, 1957. Of the capacity under construction at the close of the year, 3667·5MW was being installed in T.V.A. steam power stations, 110·5MW in T.V.A. hydro-electric plants, and the remaining 146·8MW in the Old Hickory and Cheatham projects of the U.S. Army Corps of Engineers on the Cumberland River and in the Tennessee Creek plant of the Aluminum Company of America. During the fiscal year, T.V.A. completed the Fort Patrick Henry dam, which was the twentieth major dam T.V.A. had designed and built in the past twenty years.

The following table summarises the construction work undertaken during the fiscal year 1954, the generating units completed and the units still under construction :—

Projects	Number of generating units	Kilowatt capacity
Steam-electric plants :		
Shawnee	8	1,080,000
Colbert	4	720,000
Widows Creek	2	225,000
Kingston	9	1,440,000
John Sevier	3	540,000
Gallatin	2	450,000
Total	28	4,455,000
Dams : Hydro-electric plants :		
Fort Patrick Henry	2	36,000
Boone	1	25,000
Total	3	61,000
New units in existing dams :		
Cherokee	1	30,000
Douglas	1	26,000
Fontana	1	67,500
Hiwassee	1	59,500
Chatuga	1	10,000
Nottely	1	15,000
Total	6	208,000
Cumberland River dams (U.S. Army Corps of Engineers) :		
Dale Hollow	1	18,000
Old Hickory	4	100,000
Cheatham	3	36,000
Total	8	154,000
Aluminum Company of America dams :		
Bear Creek	1	9,000
Tennessee Creek	1	10,800
Total	2	19,800
Total capacity under construction during fiscal year	45	4,897,800
Capacity under construction on June 30, 1954	32	3,924,800
Installed capacity on June 30, 1954	192	6,075,685
Anticipated installed capacity in June, 1957	224	10,000,485

As the foregoing tabulation shows, the emphasis in construction during the year was on steam-electric generating facilities. This is the result of a number of factors, of which the overriding one is national defence. During the last war, the T.V.A. shelved its long-range plans for river development in order to meet the power demands of aluminium, chemical and other industries producing war materials and of the "Manhattan District," which later became the Oak Ridge atomic energy plant. In 1949, new national defence requirements emerged, with the result that no other region of the United States is being required to divert as large a portion of its power resources to this purpose and particularly to the Atomic Energy Commission. As compared with 1500 million kWh produced in the region in 1933, T.V.A. generation in the fiscal year 1954 was 30,000 million kWh and by 1956 production will be about 60,000 million kWh a year, of which virtually half will be for national defence. Thus, the demand for electricity has far outrun the hydro-electric resources of the region which, in the peacetime period of the 1930's, were regarded by many as ample for a long time. While a number of dam sites for projects which could contribute to multiple-purpose control of water in the streams remain to be developed, they are all small in relation to the need for power. As a result, the region has had to rely upon construction of steam-electric stations for new power supplies.

Steam Power Stations

Fortunately, the region is well equipped to provide fuel-generated electric power. Economical sources of coal are to be found in Tennessee, Alabama, Eastern and Western Kentucky, and Southern Illinois. Furthermore, the orderly development of the Tennessee River and its tributaries has enhanced the value of sites for steam power plants by providing the ample water supplies demanded by modern high-temperature installations. As an example, the Kingston steam power station, when in full operation, will require 1,000,000 gallons of water per minute for cooling purposes. With four generating units having design ratings of 135MW and capabilities of 150MW and five units rated at 180MW and with capabilities of 200MW, the Kingston steam power station (Fig. 1) is believed to be the largest steam power plant under construction anywhere in the world. An interesting aspect of this station is a method of obtaining lower temperature cooling water by use of a "skimmer wall" in the reservoir from which the water is pumped. The skimmer wall—a "dam without a bottom"—is erected on piers in 40ft of water. It cuts off the flow of the warm surface water and permits the pumps to draw from the lower depths of the reservoir, where the water is coolest. The maximum temperature of the cooling water will be lowered by about 13 deg. Fah., making possible savings on the investment in condensers, condensing water facilities and pumps, and in annual pumping costs. The Kingston steam power station is on a peninsula formed by the confluence of the Clinch and Emory Rivers near Kingston, Tennessee, both at that point being part of the Watts Bar reservoir. Cooling water is pumped from the Emory River arm of the reservoir and returned after use to the Clinch River.

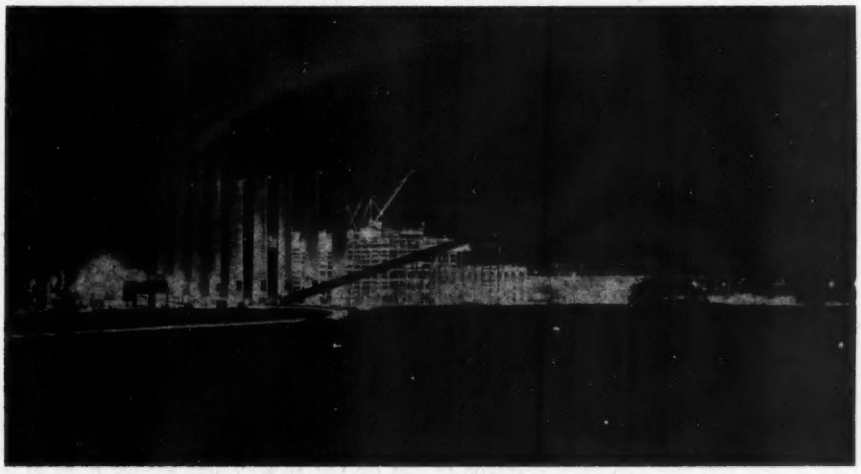

Fig. 1—The Kingston steam power station under construction on Watts Bar Lake in Tennessee. When completed the installation will have a total capacity of 1440MW

At the Shawnee steam power station, the third and fourth 135MW generating units went on the line in October, 1953, and January, 1954. T.V.A. was able to maintain a good construction schedule despite the tense labour situation in the general construction area. Substantial progress was being made at the end of the year on the other six units which the plant will have, despite delays in the receipt of boiler and turbo-generator parts. The ten units will give the plant an ultimate installed capacity of 1350MW and a capability of 1500MW. The plant is on the south bank of the Ohio River, about 12 miles west of Paducah, Kentucky.

At the Widows Creek steam power station the fifth generating unit was completed in June, 1954, and the sixth commenced initial operation the following month. This brought the plant to its planned installation of 675MW, with a 750MW capability. Construction during the year followed a revised schedule which reflected late deliveries of boiler tubing. During the early part of the fiscal year, the manufacturer completed turbine modifications which were found to be necessary after the first four units were installed. T.V.A. also made some design changes and modifications on accessory equipment. The last of the four units was returned to operation in August, 1953, and since then the units operated almost continuously at 124 per cent of rated capacity.

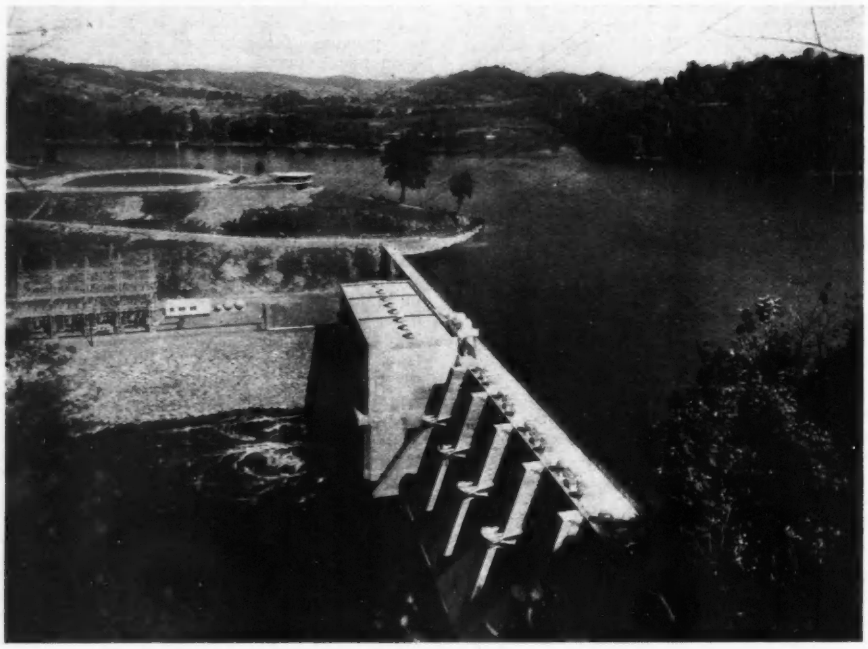

Fig. 2—The completed Fort Patrick Henry dam in Tennessee. The power station has a total capacity of 36MW

The construction of the Colbert steam power station is now well along toward completion. The first of four generating units of 180MW rated capacity and 200MW capability went into initial operation in December, 1954. The remaining three units are expected to be completed during the ensuing five months. The construction of the coal-handling facilities has been completed and the first coal delivered to the plant by barge was unloaded in June, 1954. At this project, a system of tunnels was constructed to carry the condensing water supply, in place of the pipe or culverts used at previous projects. The tunnel system proved more economical and, in addition, permitted the construction and use of yard facilities such as roads, parking areas, drainage, and underground relocations without interruptions and delays.

At the close of the fiscal year, construction of the John Sevier steam power station had been under way for twenty-one months. The first of the three generating units of 180MW rated capacity was scheduled for initial operation in June, 1955, with the second and third following in September, 1955, and March, 1956. The total installed capacity of the plant will be 540MW, with a capability of 600MW. Ultimate plans call for three additional units of the same size. The plant is on the south side of the Holston River, about 4 miles south-east of Rogersville, Tennessee. A concrete and earth detention dam is currently being built in the Holston River to supply water for condensing purposes. At the John Sevier plant, the Authority solved a special problem arising from the frequently high salt content of the Holston River due to industrial wastes. During periods of high salinity, the water cannot be successfully used to feed the boilers, even after treatment in the conventional zeolite softening system. To meet this problem, T.V.A. dammed up a nearby natural draw to form a reservoir capable of holding a two weeks' supply of raw water for the treatment plant. The pumps which take water from the river are being equipped with conductivity recorders to control them. The control system is based on the fact that water becomes a better conductor of electricity the more salty it is. Normally, the pumps will send raw water from the river directly to the treatment plant. When the water becomes too salty the electrical current passing through it will indicate this on the conductivity recorder, thus notifying the operator to stop pumping from the river. Meanwhile, the treatment plant will use water from the temporary reservoir to supply the boilers.

The Gallatin steam power station on the north bank of the Cumberland River, 9 miles south-east of Gallatin, Tennessee, was the seventh steam-electric power station to be started by T.V.A. in a period of four years. The Gallatin plant is scheduled to have two generating units each having 225MW of rated capacity and a capability of 250MW. The units are twice the size of those at the Johnsonville plant, which were regarded as large four years ago. Good progress has been made in construction since the plant was started in May, 1953. Additional experience gained in the design and planning of steam power plant, along with other considerations, provided the opportunity for a number of economies. The experience gained by the T.V.A. organisation in designing previous steam power plants proved to be of considerable value. At this particular site, T.V.A. co-ordinated its construction schedule with the plans of the U.S. Army Corps of Engineers for the completion of the Old Hickory dam and the filling of the reservoir on the Cumberland River. This eliminated the need for a costly, temporary pumping station for condensing water. The pumping costs will be reduced by building a "skimmer wall" similar to that designed for the Kingston steam power plant. A system of tunnels is being used to supply condensing water, following the experience at the Colbert and John Sevier power plants.

At the Johnsonville steam power station all six units were generating power several months before the beginning of the 1954 fiscal year. Figures published by the U.S. Federal Power Commission for 1952, in the fifth annual supplement of Steam Electric Cost and Annual Production Expenses, revealed that Johnsonville, with four units in operation, led in efficiency for non-reheat steam power stations in the United States and ranked among the ten most efficient steam power plants in the country. This was the first steam power plant designed and built by the T.V.A. in its present power expansion programme. The construction activities at Johnsonville during the past year were concerned principally with the installation and modification of mechanical and electrical equipment to improve operations. These included a number of alterations to improve the efficiency of the steam generators. Major modifications of the boilers were completed on four of the six units. Three of the six smoke stacks were raised from 170ft to 270ft in height, and similar 100ft extensions of the remaining three were under way. Two additional coal conveyors were installed and an extensive revamping of the harbour dolphins and docking facilities was completed. The installation of additional automatic coal sampling equipment in the hopper building was virtually complete.

It is of interest to note that the considerable size and extent of the present steam power plant expansion programme has provided opportunities for advances in steam power plant design and engineering, both on the part of equipment manufacturers and of the T.V.A. design organisation. The fact that the T.V.A. grid is the largest in the country permits it to use generating units much larger than had ever been designed before. On a system of large generating capacity the outage of a single generating unit—whether for regular overhaul or repair or because of a breakdown—is not so disruptive as on a small system. Hence, the Authority has found it possible in successive steam power stations to increase the size of the units. When T.V.A. commenced the construction of the Watts Bar steam power plant in 1940, the four 60MW generating units were among the largest then used in the country. In 1949, when T.V.A. started the construction of the Johnsonville plant, the units were practically doubled in size, to 112·5MW. Units of the same size were decided upon for the Widows Creek plant. At Shawnee, the first of the steam power plants started specifically to provide electricity for the A.E.C. atomic energy plant at Paducah, Kentucky, the size of the individual units was increased again, this time to 135MW. The initial four units at Kingston, started at the same time, were of the same size. For the Colbert steam power plant, the first two of the four units of 180MW each, were, when ordered, the largest ever proposed by any American utility system. Units 5 to 9 at Kingston are also of this size, as are the three units at the John Sevier plant. Now these units appear small when compared to the two units of 225MW capacity each, which are to be installed at the Gallatin plant. These larger units, with their higher temperatures and higher steam pressures, have made possible substantial operating economies, particularly in the use of fuel. The Watts Bar plant, which was one of the most efficient plants in the country at the time of its construction, has a net plant heat rate of 11,560 B.Th.U. per kilowatt-hour. At the Johnsonville plant, which also was the most efficient of its kind when completed, the rate is 10,200 B.Th.U. per kilowatt-hour. At the Gallatin plant, started in 1953 and to be in operation at the end of this year, the net plant heat rate will be only 9250 B.Th.U. per kilowatt-hour.

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Hydro-Electric Plants

Fort Patrick Henry dam (Fig. 2)—the twentieth to be built by T.V.A. in twenty years—was "closed" in October, 1953, and the two 18MW generating units were placed in operation in December, 1953, and February, 1954, respectively. It is on the South Fork of the Holston River, 2½ miles upstream from Kingsport, Tennessee. The dam is relatively small, 95ft high and 737ft long, and provides only 4300 acre-feet of storage. Its chief function is to take advantage of the upstream storage provided by the South Holston, Watauga, and Boone dams. The power station is operated, economically and at a saving in manpower, by remote control from Boone dam, which is 10 river miles upstream. At the Boone dam, which was "closed" during the previous fiscal year, the last of three 25MW generating units went into commercial operation in September, 1953, bringing the plant to its full installation of 75MW. This dam is 160ft high and 1532ft long, and is situated just below the confluence of the South Fork Holston and Watauga Rivers and backs the water up these streams 16 and 15 miles, respectively. The reservoir adds about 150,000 acre-feet of useful storage to the T.V.A. water control system. In power operations, the Boone hydro-electric plant benefits from the upstream regulation provided by the South Holston and Watauga dams.

Work proceeded during the past year in the installation of new hydro-electric units at existing dams. Two were placed in operation, one at the Fontana dam (Fig. 3) and the other at the Cherokee dam. At Fontana, a 67·5MW unit began generating on February 4, 1954, bringing the plant to its full installation of three units with a total of 202·5MW. The 480ft height of the Fontana dam makes it the highest of the T.V.A. dams. Water stored by Fontana dam, besides producing power at its own generators, increases electric output at ten dams downstream. At the Cherokee dam, on the Holston River, the fourth and last 30MW unit was placed in operation in October, 1953. The total installation at this plant is now 120MW. Despite delays in the delivery of imbedded parts, the installation of the fourth generating unit at the Douglas dam on the French Broad River was completed in August, 1954. This completed the ultimate installation of 112MW, consisting of two units of 30MW and two of 26MW. At the Hiwassee dam, preliminary construction work on the installation of a pump turbine progressed satisfactorily (Fig. 4). Work was started in January, 1954, and by late May the cofferdam had been completed and the construction area unwatered. The pump turbine will have a capacity of 59·5MW when acting as a generating unit and, added to the existing 57·6MW unit now in use at Hiwassee, will bring the total installation to 117·1MW. Acting as a pump, the unit will be capable of returning water to the reservoir at the rate of 3900 cusecs when pumping against a head of 205ft. The water will be pumped from the Apalchia dam reservoir, which extends to the foot of the Hiwassee dam. The economy of the unit is based on the fact that it can be operated as a pump by off-peak power to return water to the reservoir to maintain the power head and to be re-used through the turbines to produce much more valuable on-peak power. The Hiwassee unit is scheduled for operation in mid-1955.

The T.V.A. transmission grid, which links together the system of hydro-electric and steam power plants and transmits power to the municipal, co-operative, industrial and Federal wholesale power consumers, was increased by 657 circuit miles of line during the year, bringing the total to more than 9600 miles. Most of the expansion—367 circuit miles—was at 154kV, the rest being at lower voltages, chiefly 66kV and 44kV. A substantial part of the transmission system expansion comprised lines to transmit power to rapidly growing national defence loads, principally those of the U.S. Atomic Energy Commission, but an even larger proportion was required to supply electricity for other loads throughout the area.

With the growth of the T.V.A. system, including the addition of new generating units, new lines and new sub-stations, the communication facilities essential to an integrated system have been extended to keep pace. During the first half of the past year three major micro-wave radio relay links were placed in operation. These major links—between Chattanooga, Tennessee, and Wilson dam, Alabama, Wilson dam and Jackson (Tennessee) and Chattanooga and Nashville (Tennessee)—made up most of the 358 miles placed in operation during the year. Other links were under construction, and when they are completed T.V.A. will have 710 miles of micro-wave links. Virtually all of them will provide twenty-three communication circuits each. At the close of the year, T.V.A. had fifty-two fixed wireless stations and 266 mobile stations in operation to provide communication between supervisors and construction and repair crews in the field. A facsimile communication system, which was used first between Chattanooga and Wilson dam last year, proved so successful that similar service has been installed between Chattanooga and all other despatching offices of the T.V.A. system.

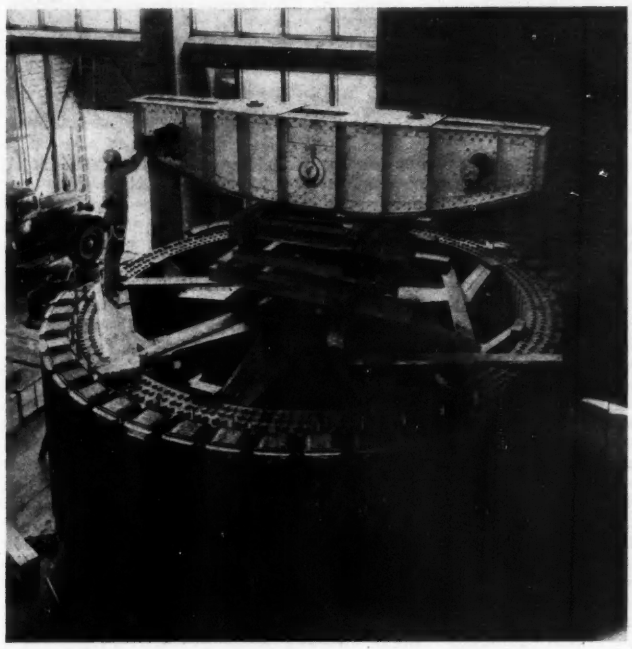


Fig. 3—Assembly of rotor of third 67·5MW turbo-generator at the Fontana dam in North Carolina. The power station now has a total capacity of 202·5MW

Multiple-Purpose Water Control

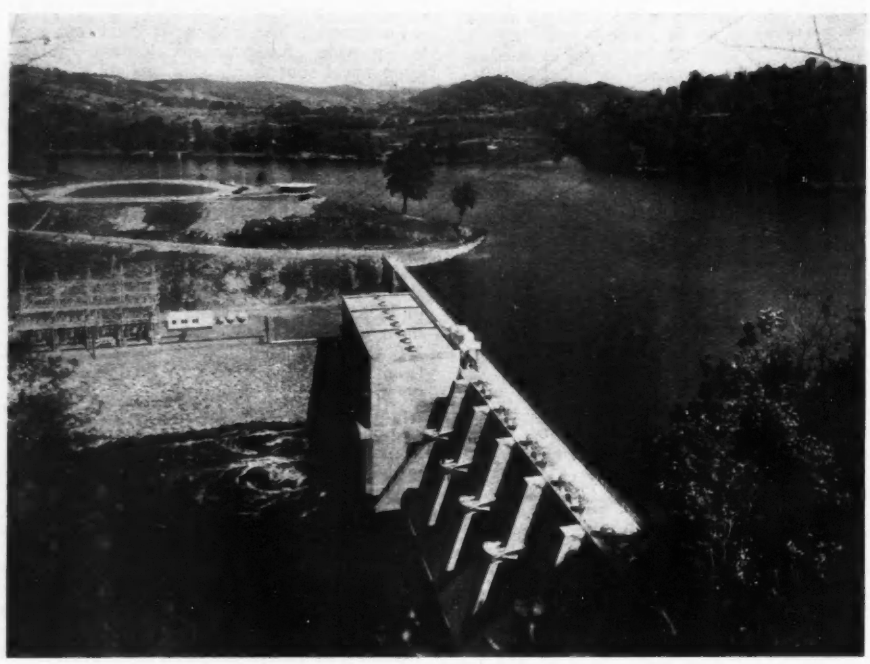
During the fiscal year 1954 the Authority operated its multiple-purpose system to control two floods, to maintain the navigation channel for a rapidly increasing volume of traffic, and to utilise stored water to maintain a high level of power production in spite of two years of subnormal rainfall. Besides these basic operations, T.V.A. regulated the flow of the river for a variety of subsidiary purposes, such as controlling malaria mosquitoes and supplementing low stream-flows in the lower Ohio and Mississippi Rivers. The T.V.A. Act provides that the Authority shall operate the system "to regulate the streamflow primarily for the purposes of promoting navigation and controlling floods" and to produce electric power "so far as may be consistent with such purposes." With the addition of the Fort Patrick Henry dam, the T.V.A. system now consists of thirty major dams and reservoirs on the Tennessee and its tributaries. Under the guide curve worked out for operation of the system, the reservoirs have at least 11,802,900 acre-feet of storage space available for flood control on about January 1st of each year, the beginning of the flood season, and at least 10,399,700 acre-feet of storage space available on March 15th, at the end of the major flood season. During the late spring and early summer at least 2,473,900 acre-feet of storage space is reserved for flood control.

During the past several years the Tennessee Valley region has had below normal rainfall and run-off. The amount of useful water in storage at the end of the present year was less than at the beginning, repeating the experience of the previous fiscal year. On July 1, 1953, the reservoirs contained 6,690,000 acre-feet of useful water, and on June 30, 1954, 6,190,000 acre-feet, a net reduction of 500,000 acre-feet, or 7½ per cent. About 80 per cent of the stored water at the end of the year was in the reservoirs upstream from the Chicamauga dam, situated just above Chattanooga. These low-flow conditions were a continuation of those of the previous year, but were more severe. Consequently, except when flood conditions prevailed in January, the operation of the reservoir system was directed principally to the conservation and use of the available water to meet the hydro-electric power demand and to maintain depth needed for navigation without prematurely exhausting the supply of stored water. By January 1, 1954, the storage reservoirs on the tributary streams had been drawn down well below the levels required to provide the planned flood control storage space and in some cases nearly to minimum operating levels for power production. When the drought was broken by flood-producing storms in mid-January, all the tributary reservoirs were unusually low and some critically so. Useful water in storage reached the low point in January, when only 643,000 acre-feet was in storage. The maximum for the year, 7,076,000 acre-feet, was reached in early June, 1954.

In January, 1954, the reservoir system was operated to reduce the crests of two floods which, under natural conditions, without regulation by the T.V.A. reservoirs, would have exceeded the 30ft flood stage at Chattanooga. Flood control measures reduced the crest of the second, and larger, of these floods by 12·2ft, preventing damage estimated at 7,600,000 dollars at Chattanooga. Substantial damage was averted at other points along the river, but no monetary estimate was made. Under natural conditions, the flood would have reached a crest of 42ft on the Chattanooga gauge; the regulated crest was 29·8ft. The crest of the flood on January 17th was held to a stage of 24·1ft. With the January, 1954, flood, the cumulative savings in flood damage at Chattanooga—the most critical point of flood danger in the Tennessee Valley—reached 52,916,000 dollars. Since 1936, when the first multiple-purpose project—Norris dam—

At the Shawnee steam power station, the third and fourth 135MW generating units went on the line in October, 1953, and January, 1954. T.V.A. was able to maintain a good construction schedule despite the tense labour situation in the general construction area. Substantial progress was being made at the end of the year on the other six units which the plant will have, despite delays in the receipt of boiler and turbo-generator parts. The ten units will give the plant an ultimate installed capacity of 1350MW and a capability of 1500MW. The plant is on the south bank of the Ohio River, about 12 miles west of Paducah, Kentucky.

At the Widows Creek steam power station the fifth generating unit was completed in June, 1954, and the sixth commenced initial operation the following month. This brought the plant to its planned installation of 675MW, with a 750MW capability. Construction during the year followed a revised schedule which reflected late deliveries of boiler tubing. During the early part of the fiscal year, the manufacturer completed turbine modifications which were found to be necessary after the first four units were installed. T.V.A. also made some design changes and modifications on accessory equipment. The last of the four units was returned to operation in August, 1953, and since then the units operated almost continuously at 124 per cent of rated capacity.



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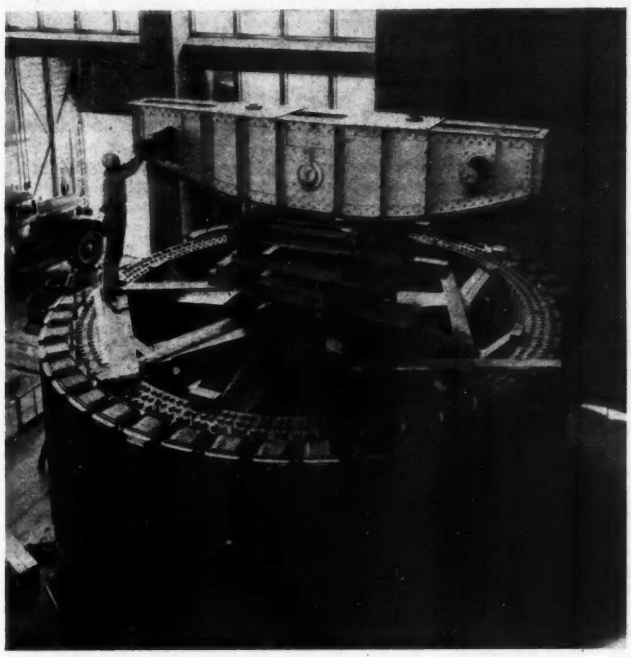

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Multiple-Purpose Water Control

During the fiscal year 1954 the Authority operated its multiple-purpose system to control two floods, to maintain the navigation channel for a rapidly increasing volume of traffic, and to utilise stored water to maintain a high level of power production in spite of two years of subnormal rainfall. Besides these basic operations, T.V.A. regulated the flow of the river for a variety of subsidiary purposes, such as controlling malaria mosquitoes and supplementing low stream-flows in the lower Ohio and Mississippi Rivers. The T.V.A. Act provides that the Authority shall operate the system "to regulate the streamflow primarily for the purposes of promoting navigation and controlling floods" and to produce electric power "so far as may be consistent with such purposes." With the addition of the Fort Patrick Henry dam, the T.V.A. system now consists of thirty major dams and reservoirs on the Tennessee and its tributaries. Under the guide curve worked out for operation of the system, the reservoirs have at least 11,802,900 acre-feet of storage space available for flood control on about January 1st of each year, the beginning of the flood season, and at least 10,399,700 acre-feet of storage space available on March 15th, at the end of the major flood season. During the late spring and early summer at least 2,473,900 acre-feet of storage space is reserved for flood control.

During the past several years the Tennessee Valley region has had below normal rainfall and run-off. The amount of useful water in storage at the end of the present year was less than at the beginning, repeating the experience of the previous fiscal year. On July 1, 1953, the reservoirs contained 6,690,000 acre-feet of useful water, and on June 30, 1954, 6,190,000 acre-feet, a net reduction of 500,000 acre-feet, or 7½ per cent. About 80 per cent of the stored water at the end of the year was in the reservoirs upstream from the Chicamauga dam, situated just above Chattanooga. These low-flow conditions were a continuation of those of the previous year, but were more severe. Consequently, except when flood conditions prevailed in January, the operation of the reservoir system was directed principally to the conservation and use of the available water to meet the hydro-electric power demand and to maintain depth needed for navigation without prematurely exhausting the supply of stored water. By January 1, 1954, the storage reservoirs on the tributary streams had been drawn down well below the levels required to provide the planned flood control storage space and in some cases nearly to minimum operating levels for power production. When the drought was broken by flood-producing storms in mid-January, all the tributary reservoirs were unusually low and some critically so. Useful water in storage reached the low point in January, when only 643,000 acre-feet was in storage. The maximum for the year, 7,076,000 acre-feet, was reached in early June, 1954.

In January, 1954, the reservoir system was operated to reduce the crests of two floods which, under natural conditions, without regulation by the T.V.A. reservoirs, would have exceeded the 30ft flood stage at Chattanooga. Flood control measures reduced the crest of the second, and larger, of these floods by 12·2ft, preventing damage estimated at 7,600,000 dollars at Chattanooga. Substantial damage was averted at other points along the river, but no monetary estimate was made. Under natural conditions, the flood would have reached a crest of 42ft on the Chattanooga gauge; the regulated crest was 29·8ft. The crest of the flood on January 17th was held to a stage of 24·1ft. With the January, 1954, flood, the cumulative savings in flood damage at Chattanooga—the most critical point of flood danger in the Tennessee Valley—reached 52,916,000 dollars. Since 1936, when the first multiple-purpose project—Norris dam—

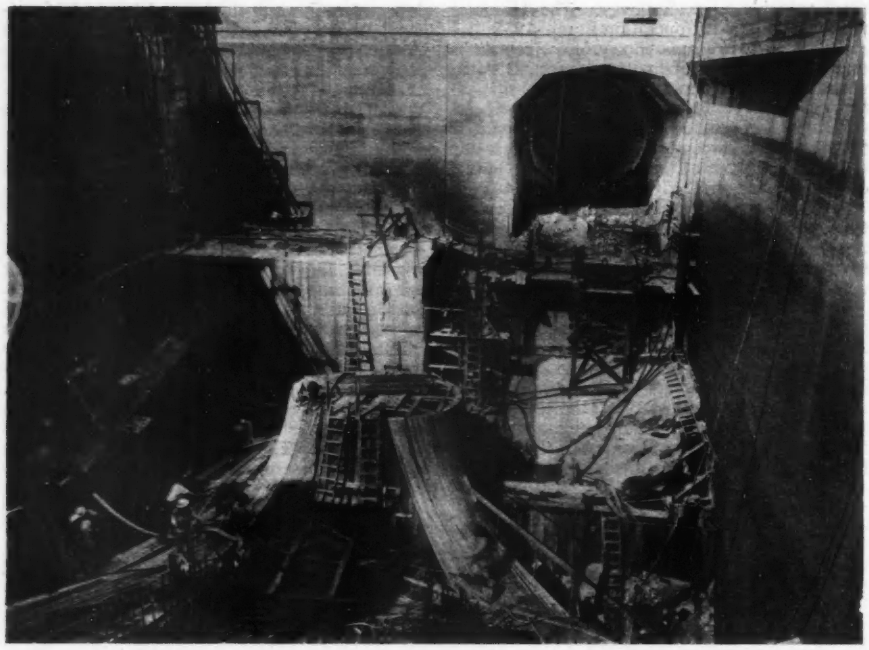


Fig. 4—Construction work at the Hiwassee dam in North Carolina preliminary to installation of 59·5MW pump turbine. When completed, the power station will have a total capacity of 117·1MW

went into operation, the T.V.A. system has reduced the crests of sixteen floods at Chattanooga.

The control of the flow of the Tennessee has a considerable effect on the stages of the lower Ohio and Mississippi rivers. Prior to the establishment of the T.V.A. the minimum flow of the Tennessee River at its confluence with the Ohio ranged as low as 5000 cusecs ; with the regulation provided by the T.V.A. reservoirs the minimum is now some four or five times that much. Sometimes operation of the reservoirs can be managed to increase the flows in the lower rivers if necessary, and an example of this occurred in 1953. In co-operation with the U.S. Army Corps of Engineers, the Authority released water from its reservoirs on the Tennessee to the lower Ohio and Mississippi rivers during the period of low river stages in the autumn of 1953, and this is estimated to have increased the stage at Cairo, Illinois, by from 1ft to 1ft 6in. This measure proved to be an appreciable assistance to barge traffic, enabling heavier cargoes to be carried.

Traffic continued to grow rapidly on the Tennessee waterway, which constitutes a link in the 9000-mile network of improved navigation channels connecting twenty of the forty-eight States and affecting a trade area from the Atlantic Coast to the Rocky Mountains. In the first nine months of the calendar year 1954, it was estimated that approximately 910 million ton-miles of traffic were moved on the Tennessee. The contribution of the waterway to commerce is indicated by the diversity, as well as the volume, of traffic. Incoming traffic included grain from the Mid-West to help make up the annual deficit in the valley region of more than 1,000,000 tons. Petroleum products from refineries of the South-West and Mid-West were distributed to half a dozen South-Eastern States from Tennessee River ports. Automobiles manufactured in the Northern States were brought by barge for distribution to eight South-Eastern States. In addition to large amounts of coal transported to T.V.A. steam power stations, coal loaded on the Ohio River moved on the Tennessee to a private power plant in Georgia. Salt and sulphur from points along the Gulf Coast were barged into the valley to supply the growing chemical industry. Other incoming traffic included molasses from Cuba, manganese ore from the Pittsburgh area, and steel from the Pittsburgh and Chicago districts. Outgoing traffic, although not so voluminous, included iron and steel scrap for the Pittsburgh steel mills, ferro-alloys to destinations on the Great Lakes and the upper Ohio River, domestic and industrial coal from the Tennessee and Kentucky mines to St. Paul and Minneapolis, pig iron from Tennessee and Alabama to Ohio, Wisconsin, and Illinois steel mills, and fertiliser from the T.V.A. Mussel Shoals chemical plant to Wisconsin and Minnesota. New vessels built at shipyards at Decatur, Alabama, were placed in service throughout the inland waterway system.

An example of the part which water transportation plays in encouraging the development of industry is provided by the new paper and pulp mills of the Bowaters Southern Paper Corporation, which went into full-scale operation in the autumn of 1954 producing newsprint for the American market. The plant, which was described in our issues of September 3 and 10, 1954, is situated 18 miles above the mouth of the Hiwassee River, a tributary channel made navigable by the Chickamauga dam. The availability of water transportation, along with favourable highway and rail connections, was an important factor in selecting the site for the works. It will use pulpwood from producing areas in Virginia, North and South Carolina, Kentucky, Tennessee, Alabama, Mississippi and Georgia. The company has obtained authority from the Interstate Commerce Commission to ship pulpwood and wood chips in company-owned barges from twelve points along the Tennessee River. Barges, as well as rail and truck facilities, will be used to ship the newsprint.

Malaria Control

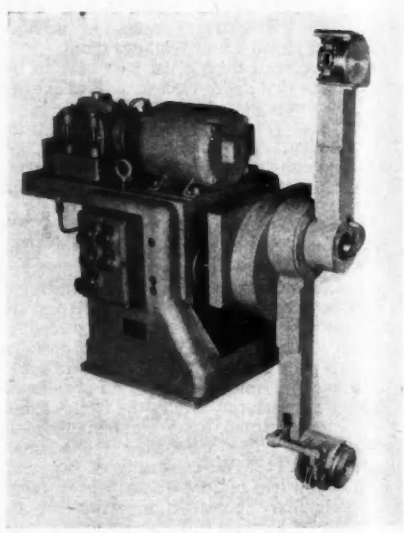
Malaria control measures developed and applied by the Authority have reduced the incidence of the disease to the point of virtual disappearance along the Tennessee River. Both private interests and other governmental agencies have utilised these techniques on other impoundages in the United States. Control by water level management has been developed to a high degree. This calls for fluctuation of reservoir levels to produce an environment unfavourable to malaria mosquitoes. In addition, T.V.A. utilises other techniques such as larviciding, maintenance of clean shorelines by vegetative control measures, and permanent shoreline improvements. The comprehensive programme was undertaken at the beginning of the T.V.A. operations to ensure that the construction of the reservoirs would not increase the malaria hazard in a region where it had long been prevalent. A house-to-house survey in 1934 revealed, by means of blood samples examined in the laboratory, that 30 per cent of the people along the river in North Alabama had malaria. The effectiveness of the T.V.A. control measures is indicated by the fact that the incidence of the disease has declined practically to the vanishing point.

Automatic Loading and Unloading Machine

An interesting automatic loading and unloading unit for machine tools, which is shown in the accompanying illustration, has been developed by the Hautau Engineering Company, of Ferndale, Michigan.• The equipment is particularly adaptable to use with horizontal spindle machines such as lathes and grinders. It is compact and may be used in many applications where space limitations have previously eliminated the possibility of loading automatically. The loader feeds a part to the machine from an incoming conveyor or a preceding machine and simultaneously removes a finished part from the machine to an outgoing conveyor.

The machine has two arms which swing through 180 deg. arcs about a central axis and carry work clamps on their outer ends. While one arm is unloading a finished part from the machine, the other arm is picking up a new part from the incoming conveyor. When the machine has completed its cycle, both arms move over the respective workpieces, and the clamps close around them. The arms then elevate to clear the fixtures and then index through 180 deg. exchanging position. The arms are now lowered and the clamps open, depositing the finished part on the output conveyor and a new part in the machine tool. Since both arms index through the same path, passing each other, only 180 deg. of clearance are needed for the arms instead of the usual 360 deg. To avoid the parts striking each other as the arms pass, one arm is made shorter than the other and the central hub reciprocates about an eccentrically mounted shaft through a 180 deg. arc. Since the hub reciprocates so as to favour the shorter arm, both arms operate between the same two points. If it is desired to have the finished part returned to a position other than its starting point the arc of travel of either the arms or the hub may be varied.

The work clamps are opened and closed through the action of pneumatic cylinders which are situated in the arms. The movement of the arms and the turning and lifting of the central hub are accomplished by a cam-actuated mechanism which moves on preloaded ball bearing slides. The cams are powered by an electric motor which acts through a speed reducer and an electrically actuable clutch and brake set. The cam shape is derived from cycloidal functions resulting in a minimising of shock on the driving members and a better load-time distribution. The clutch and brake are controlled by limit-switches which allow the loading machine to be connected in timed sequences with the other production equipment. The machine may be mounted either on its own heavy cast base or directly on the machine tool or the conveyor.



Automatic loading and unloading machine handling pistons

Industrial and Labour Notes

London Underground Railway Wages

At the end of last week it was announced that wage increases, retrospective to January 2nd, were to be paid to London underground railway workers, following an award by the London Transport Railway Wages Board. The increases vary between 9s. 6d. and 22s. 6d. a week, according to grade and length of service.

The negotiations, which preceded the consideration of the matter by the wages board, failed mainly on the question of motormen's pay. The London Transport Executive took the view that motormen's wages should be below those of main line locomotive drivers, but the Associated Society of Locomotive Engineers and Firemen made application "for increases in rates comparable with those awarded on the main line railways." The National Union of Railwaymen submitted a similar claim for motormen, and for other grades asked that increases of 15 per cent on the rates applying prior to December, 1953, should be granted.

In announcing its award, the London Transport Railway Wages Board said that it accepted the principle that the rates of pay of all conciliation grades on London Transport Railways should be determined by the nature and responsibility of their duties and the conditions under which they worked. There could be no complete uniformity, the wages board stated, between the rates paid on London Transport railways and the main line railways. About the particular case of the motormen, the board said that it was unable to find any ground for disturbing the relationship which had existed for some thirty-five years between rates payable to this grade on the London Transport railways and on the main line railways.

Output of Iron Castings

The Council of Ironfoundry Associations has stated that last year's output of iron castings in the United Kingdom was 3,742,000 tons, or 2·9 per cent higher than in 1953. The Council says that in the ironfounding industry the overall level of activity was fairly steady for most of the year, after allowing for normal seasonal influences, but that there was considerable expansion during the last quarter.

Surveying the various sections of the industry, the Council says that last year's output of iron castings for cars, commercial vehicles, cycles and motor-cycles was 316,000 tons, or 16·5 per cent more than in 1953, and that castings for agricultural machinery (mostly for tractors) were 183,000 tons, or 27·5 per cent above the quantity produced in 1953. Castings for building and domestic requirements totalled 566,000 tons last year, an increase of 3·3 per cent on 1953. The Council's survey adds that of the twenty-two ironfounding districts in the United Kingdom, fourteen had a higher output last year than in 1953. The West Midland counties, which are a major centre of the ironfounding industry, increased their output by nearly 10 per cent over 1953.

Iron and Steel Realisation and Holding Agency

The first annual report of the Iron and Steel Holding and Realisation Agency has now been published. It covers the period from July 13, 1953, which was the day appointed for the Agency to begin its operations, until September 30, 1954.

The report says that on the "appointed day" the securities of seventy-one iron and steel companies were vested directly in the Agency. These companies were themselves the sole or majority holders of the capitals of 231 subsidiaries, so that actually on the appointed day 302 companies became subsidiaries of the Agency. The book value of the securities in the seventy-one companies and their subsidiaries was £252,300,000, to which must be added £10,100,000 for further investments made by the Agency. The responsibility of the Agency, of course, has been to secure the return of these concerns to private ownership. By September 30th last, thirteen companies and their 126 subsidiaries had ceased to be subsidiaries of the Agency, and the report explains that in terms of employment, steel production and sales, these companies collectively represented about one-third of the Agency's inheritance. The gross realisation proceeds from these thirteen companies have so far amounted to £78,000,000, of which £68,600,000 came from the sale of securities and £9,400,000 came from the redemption of securities and the cancellation of debt before sale. The Agency retained £14,900,000 for investment and other purposes, and the net amount paid over to the Treasury on capital account was £63,100,000, comprising £17,100,000 in Government securities and £46,000,000 in cash. In addition, as regards revenue account, the Agency paid over to the Treasury its net revenue for the year, amounting to £3,000,000.

Census of Production

The Board of Trade has stated that firms which are required to make a census of production return for the year 1955 have already been notified. The census, which will be taken next year, is to be a simplified sample survey similar to those taken in respect of 1952 and 1953, for which only about one-tenth of the total number of manufacturers in the country were required to make a return. New establishments which come into production this year may also be required to make a return in the census and any such establishments which come within the sampling scheme will be advised as soon as possible after the census office is notified that they are in production.

The advisory committee for the 1956 and 1957 censuses of production has been appointed. The function of this statutory committee is to advise on the preparation of forms and instructions, and the making of any order, for the census to be taken in 1957 in respect of the year 1956, and for the census to be taken in 1958 in respect of 1957. Part of the committee's task will be to tender advice on carrying out the recommendations of the Verdon Smith report (which was published in October last) for reducing the burden on the business community and simplifying the censuses, especially for smaller firms. The chairman of the committee is Mr. J. Stafford, and the secretary is Miss J. M. N. Milne, of the Statistics Division, Board of Trade, Lacon House, Theobald's Road, London, W.C.1.

Trade Unions and Productivity

In a note which he has contributed to the *B.P.C. Bulletin*, Mr. James Crawford, deputy chairman of the British Productivity Council, says that trade unions believe that emphasis should be laid upon making work more effective by the improvement of methods rather than upon working harder. Trade unions and employers alike, Mr. Crawford adds, believe that the demand for goods and services should be maintained at a high level and that all possible measures should be taken to prevent higher productivity from leading to redundancy.

Within this field, he suggests, employers' organisations and trade unions can do much to create a favourable climate. Management, Mr. Crawford says, has a great responsibility for taking into account the problems of human relations, spreading the knowledge of techniques which have been found to give good results, and discussing and reaching agreement with trade unions regarding the general principles under which programmes of higher productivity should be achieved. It is particularly important, Mr. Crawford thinks, that all the safeguards which can be applied to take care of human values should be implicit in such an agreement. The job of management, he goes on to say, is to look ahead and visualise the effect of policy on future labour requirements, especially where technological improvements or other changes are introduced. In this connection, Mr. Crawford urges, it will be helpful if the modern techniques of work study are not regarded by management as an exact science, but are regarded as no more than a technical method of assisting management and trade unions to find solutions for problems which are as much human as technical.

The trade unions, Mr. Crawford continues, have an important function to perform. Their primary function is "to defend and promote the best interests of their members." The unions, therefore, will be influenced by whether management is willing or unwilling to accept the principle that the techniques of modern management methods, including work study, are obviously subjects for industrial negotiation. Trade unions, Mr. Crawford emphasises, can co-operate with management, and should do so, in working out procedures which will provide safeguards for their members when affected by technological or other change.

Managing the Small Firm

The British Institute of Management has announced some details about the third annual conference concerned with the management problems of small firms. This conference is to be held at Harrogate on Friday and Saturday, April 29th and 30th. It is stated that there are no rigid limitations as to the kind of firm which will find this conference of interest. Whilst the basic problems of management are very similar regardless of the size of the undertaking, it is well-known that the directors and senior management of a small firm have to face one situation that is somewhat different from that of their counterparts in a larger firm; they often have to be their own specialists. The conference has, therefore, been designed to cover all the main fields of management, including financial management, marketing, personnel and production. The object, it is stated, is not the prescription of easy solutions to management's troubles, but the free and informal exchange of views among people with common interests and common problems.

Industrial Disputes

Figures published in the latest number of the *Ministry of Labour Gazette* show that during January there were 199 stoppages of work in the United Kingdom on account of industrial disputes. Of that number, eight started before the end of last year. In these 199 stoppages of work, 43,800 people were involved directly and indirectly during January, the aggregate number of working days lost being 91,000. The majority of the stoppages, 142 in all, occurred in the coal mining industry, in which 41,000 working days were lost during January by 20,900 men. Most of these stoppages were short, though there was one, affecting 1500 mineworkers at a colliery in South Wales, which lasted for eight days. A prolonged stoppage of work included in the January statistics, is that of steel erectors in various parts of the country. The dispute, which has been going on since the end of October last, is concerned with a claim for increased wages.

Steel and Coal

Steel production in Great Britain during the month of February averaged 394,200 tons a week, and was thus running at an annual rate of 20,498,000 tons, which is the highest ever achieved by the industry. In February last year, the annual rate of steel production was 18,577,000 tons. Pig iron output in February averaged 241,700 tons a week, which represented an annual rate of 12,567,000 tons, compared with a rate of 11,557,000 tons in February last year.

The latest figures concerning coal output in Great Britain show that in the first nine weeks of this year ended last Saturday, deep-mined production amounted to 38,875,400 tons and opencast production 1,399,600 tons, giving a total of 40,275,000 tons. In the comparable period of last year total output amounted to 41,356,500 tons. Last week's output from the deep mines was 4,378,600 tons, or 6000 tons below the amount produced in the corresponding week of 1954. Opencast output last week was 192,100 tons, which was 5000 tons above the figure for the comparable week of last year.

Personal and Business

Appointments

MR. S. F. MITMAN has been appointed deputy chairman and managing director of Borg-Warner, Ltd.

DUNLOP, Ltd., announces the appointment of Mr. J. W. Tidswell as works manager of the Hirwaun factory.

MARINE AND INDUSTRIAL LUBRICANTS, Ltd., states that Mr. John E. Harvey, general manager, has been appointed a director.

BRITISH INSULATED CALLENDER'S CABLES, Ltd., announces the appointment of Mr. R. H. Steeds as regional manager for Scotland.

SIR HAROLD ROXBEE COX has been appointed an independent member of the council of the Air Registration Board in place of the late Sir Maurice Denny.

AIR MARSHAL SIR VICTOR GODDARD, K.C.B., has joined Elliott Brothers (London), Ltd., Lewisham, S.E.13, as an assistant (air) to the managing director.

MR. P. A. ANDREW has joined the board of United Marine (1939), Ltd., 64, Queen Street, London, E.C.4. He was formerly sales director of Export Packing Service, Ltd.

LONDON TRANSPORT states that Mr. A. E. Flack has been appointed divisional superintendent (N.W. Division) in the department of the operating manager (central road services).

PROFESSOR L. J. KASTNER, professor of engineering and head of the engineering department, University College of Swansea, has been appointed to the University of London chair of mechanical engineering, tenable at King's College.

THE BRITISH BROADCASTING CORPORATION announces the appointment of Mr. W. R. Fletcher as engineer-in-charge at the Brookmans Park transmitting station. He succeeds Mr. D. Hamilton-Schasehke, who has been appointed resident engineer, British Far Eastern Broadcasting Service, Singapore.

MR. F. BATEMAN and Mr. R. F. Marshall have been appointed assistant managers of the education department of Metropolitan-Vickers Electrical Company, Ltd., Trafford Park, Manchester. The company states also that Mr. D. R. Davies, M.I.E.E., of the switchgear engineering department, has been appointed consulting designer.

THE BRITISH THOMSON-HOUSTON COMPANY, Ltd., announces the appointment of Mr. E. Alexander, A.M.I.E.E., as manager of the Willesden works in succession to Mr. H. E. Cox, who has become manager of the Rugby works. Mr. Alexander joined the company in 1924 and has been general superintendent at the Willesden works since 1946. The company also announces the appointment of Mr. C. F. Humphreys as manager of the switchgear engineering department and of Dr. J. R. Mortlock, M.I.E.E., as manager of the power system engineering department.

ENFIELD CABLES, Ltd., Victoria House, Southampton Row, London, W.C.1, announces the appointment of Mr. H. E. Tickner as works manager (cables) in charge of its three cable-making works. He has been in the company's service for thirty-two years and in his new appointment he succeeds Mr. R. A. Kirby, who is joining the staff of Enfield Cables (Australia) Pty., Ltd. Enfield Cables, Ltd., also states that its subsidiary cotton covering factory at Blaenavon has been closed and its production transferred to the main works at Brimsdown. Mr. W. G. Turner, who was in charge of the Blaenavon factory, has been appointed manager of the covered wires department at Brimsdown.

Business Announcements

ASSOCIATED ELECTRICAL INDUSTRIES, Ltd., states that it has now acquired the whole of the undertaking of Australian General Electric Pty., Ltd.

MR. D. S. BARWELL, sales promotion manager (export) of Johnson and Phillips, Ltd., Charlton, London, S.E.7, is engaged on a tour of the Middle East.

THE HUNTING GROUP announces the formation of a new company, Adastra Hunting Geophysics, Ltd., to carry out airborne geophysical surveys in Australia.

HENRY MEADOWS, Ltd., Wolverhampton, has formed a gearbox division to deal with the production and sales of marine, automotive and industrial gearboxes.

THE WHARTON CRANE AND HOIST COMPANY, Ltd., Reddish, has opened a London office at Lincoln Chambers, Portsmouth Street, W.C.2, under the control of Mr. K. A. Bowman.

THE ENGLISH ELECTRIC COMPANY, Ltd., has opened a sub-office at Barclays Bank Chambers, 3, Trinity House Lane, Hull (telephone, Hull 35533). Mr. M. S. R. Thompson is in charge of the office.

THE RUGBY PORTLAND CEMENT COMPANY, Ltd., has disposed of the whole of the share capital of The Scottish Construction Company, Ltd., to The Trussed Concrete Steel Company, Ltd.

SIR CHARLES COLSTON, who recently resigned from the vice-chairmanship of the Independent Television Authority, has announced the formation of a new company specialising in the manufacture of labour-saving household appliances. The company will be called Charles Colston, Ltd.

MONSANTO CHEMICALS, Ltd., announces that steps are being taken to form a new wholly-owned subsidiary to be known as Monsanto Phosphates, Ltd. The company will erect and operate plants in Great Britain for the production of sodium phosphates and other phosphorus compounds. Mr. J. M. Kershaw is to be the general manager of the new company.

Contracts

A BRIDGE over the Chambal River, near Agra, on the Indian National Highway connecting Bombay with Agra, has been designed and will be built by the British firm of Gammon India, Ltd. The Chambal bridge will be 2434ft long, with foundations reaching to a depth of 60ft below low water level and with spans up to 143ft each. The bridge is designed to be submerged as much as 27ft during the monsoon floods and to withstand the loads imposed when the level of the river reaches the decking. Such high floods are, however, only exceptional, lasting for a few hours, so that the bridge will be able to carry traffic almost continuously. The same company has also secured, in international competition, a contract for a 3300ft long road bridge in prestressed concrete with 150ft spans and foundations going down 75ft below low water level. This bridge is to be constructed over the Sone River in the Mirzapur district, and must be completed in fifteen working months to serve the £9,000,000 Rihand dam project.

Miscellanea

ALUMINIUM WORKS MODERNISATION.—The Northern Aluminium Company, Ltd., states that it has commenced a modernisation programme designed to increase the output of the Banbury works by several hundreds of tons per annum. In order not to affect full production the plan will be carried out in stages and be completed in 1958, and will involve the installation of a larger hot mill capable of rolling ingots of over 1 ton in weight.

PAPERS ON WELDING.—The council of the Institute of Welding announces that papers to be considered for the award of the Sir William J. Larke medal of the Institute for 1955 must reach the secretary at the Institute's offices, 2, Buckingham Palace Gardens, London, S.W.1, not later than April 30th. Particulars of the regulations for the award of the medal, for which non-members as well as members of the Institute may compete, may be had from the same address.

COASTAL MINESWEEPERS.—On February 23rd, the coastal minesweeper H.M.S. "Leverton" was named at the Belfast yard of Harland and Wolff, Ltd. The minesweeper has a length of 152ft with a beam of 28ft 9in., will be armed with three small guns and will have main machinery built by Mirrlees, Bickerton and Day, Ltd. On February 28th, another coastal minesweeper, H.M.S. "Jackton," was launched from the Noss yard of Philip and Son, Ltd., Dartmouth.

RESEARCH SCHOLARSHIP.—The Aluminium Development Association has offered a research scholarship, to the value of £400 per annum and tenable for two years, to facilitate study in the application of light alloys to ship construction. A committee of the Institution of Naval Architects will administer the scholarship, which it is hoped to award in September this year and for which entry closes on June 30, 1955. Full particulars can be obtained from the Secretary, the Institution of Naval Architects, 10, Upper Belgrave Street, London, S.W.1.

PRODUCTIVITY STUDY COURSES.—The Institute for Engineering Production has prepared a programme setting out details of a series of short residential courses in "productivity study," which are conducted at "Southfield," 16, Norfolk Road, Edgbaston, Birmingham. These courses, which are designed specially for executives, deal with work study, production planning and control, process and product improvement, and operational research. They are directed by Professor T. U. Matthew, professor of engineering production at Birmingham University.

ASSOCIATED DYNAMO AND MOTOR MANUFACTURERS.—The annual dinner of the Associated Dynamo and Motor Manufacturers was held recently at the Trocadero Restaurant, London. Mr. F. H. Schroeder, the chairman of the Association, proposed the toast of the guests and referred to the work involved in preparing information for the Monopolies Commission. He said that he thought it would be nothing short of a disaster if the work of the Association were to be restricted or changed in any material way. Far from operating a monopoly, members of the Association had to trade in the face of keen internal (as well as non-signatory) competition, both at home and abroad. Mr. C. M. Gray responded to the toast on behalf of the guests. The toast of the Associated Dynamo and Motor Manufacturers was proposed by Sir Walter Puckey, president of the Institution of Production Engineers, and the response was made by Mr. H. W. Bosworth.

COMPLETION OF FIRST STAGE OF UGANDA'S GRID.—Sir Charles Westlake, Chairman of the Uganda Electricity Board, recently witnessed the final stages in the construction of the 132kV transmission lines which will transmit power from Owen Falls to Kampala and Tororo. The lines have a route length of 114 miles and are the first stage in the development of a grid transmission system for Uganda. At present the lines are operating at 33kV and they will be commissioned at the full voltage of 132kV later this year. The contractor for the lines was British Insulated Callender's Construction Company, Ltd.

IRELAND AIR FERRY.—A vehicle air ferry service between Great Britain and Northern Ireland operated by Silver City Airways, Ltd., has now licence approval. The company will start flying cars, cycles and passengers between Stranraer (Castle Kennedy) and Belfast (Newtownards Airport) on April 7th. The overall journey time, including loading and unloading will be thirty-five minutes by air compared with up to eight and a half hours by sea. The actual flying time for the 35-mile strip will be eighteen minutes. Bristol "170" ferryplanes will be used.

PORTABLE CONVEYOR FLIGHT-BAR STRAIGHTENER.—A portable hydraulic tool has been introduced by A. G. Wild and Co., Ltd., of Sheffield, for use in straightening damaged flight-bars on conveyors without need for removing them from the installation. The tool consists of a hydraulic ram operated by a hand lever and it is capable of exerting a pressure of 5 tons. It is braced by two legs at the rear when in use and the rear end of the body incorporates a screwed socket for the fitting of special adapters if required. The complete tool weighs some 43 lb. When it is not in use the pivoted legs can be swung back and clipped to the side of the body and the top of the lever can be locked by a clip at the end of the cylinder. This lever is bent to form a convenient handle when the tool is being carried from point to point.

PROTECTIVE INDUSTRIAL SPECTACLES.—It is often a matter of some difficulty to persuade industrial workers, particularly women, to wear protective goggles, as they object to their appearance. For this reason the Hadley Company, Ltd., Portsmouth Road, Surbiton, Surrey, has recently introduced a new safety spectacle which, whilst it affords the wearer the fullest protection against dust or flying grit, retains the smart appearance of the modern spectacle. These spectacles are made in two sizes in flesh-toned or clear crystal non-inflammable plastic material, and are light and comfortable to wear and easy to clean. The frames can be fitted with either "Triplex" unshatterable safety lenses or filter lenses, according to the requirements of the work. The side shields are pivoted on the frames so that they can be swung inwards to permit the ear pieces to be folded back to enable the spectacles to be stored in a small space.

TRANSPORTABLE VEHICLE SERVICING UNIT.—Details have been published by Auto Diesels, Ltd., Uxbridge, Middlesex, of its transportable general service unit which is designed to eliminate the delays which occur when fleets of vehicles have to queue for servicing facilities. The unit consists of a fabricated chassis mounted on castors which carries a 1·2 b.h.p., four stroke petrol engine, 24/32V, 400W d.c. generator, and battery charging equipment, and a 1·7 cubic feet per minute, 100 lb per square inch compressor. In addition, two self-priming, 1000 gallons per hour centrifugal pumps and one 160 gallons per hour positive displacement pump are fitted, each pump being driven by a ¾ h.p., 24V, drip-proof electric motor. Suction and delivery hose and compressed air hose are carried on the unit, which is also equipped with lead-acid batteries for operating the pumps. When loaded on a utility truck, together with drums for fuel, lubricant and water, the equipment forms a self-contained mobile service station.

INSTITUTION OF NAVAL ARCHITECTS.—The annual general meeting of the Institution of Naval Architects will take place at 10.15 a.m. on Wednesday, April 6th, in the Weir Lecture Hall, 10, Upper Belgrave Street, London, S.W.1. At 5.15 p.m. on Monday, April 4th, the president, Viscount Runciman, will open the Weir Lecture Hall, and this ceremony will be followed by the Amos Ayre Lecture. The following is the provisional list of papers to be read on the succeeding days :—In the forenoon of Tuesday, April 5th, Final "Lucy Ashton" paper, by Dr. S. Livingston-Smith, C.B.E., and "Recent Developments in Naval Life-Saving Equipment," by W. J. Holt, R.C.N.C., to be followed in the afternoon by "A Hundred Years of Lloyd's Register Ship Rules," by J. M. Murray, M.B.E., B.Sc., and "Forty Years of Change at Portsmouth Dockyard," by I. E. King, C.B.E., R.C.N.C. In the evening there will be a joint meeting with the Institute of Marine Engineers, when Professor G. Aertssen will read his paper, "Sea Trials on a 9500 D.W. Motor Cargo Liner." On the morning of Wednesday, April 6th, Sir William C. Currie, G.B.E., will read a paper entitled "Liners of the Past, Present and Future on Service East," and in the afternoon "The Cathodic Protection of Ships Against Sea Water" will be presented by L. T. Carter, B.Sc., R.C.N.C., and J. T. Crennell. The annual dinner will be held on Wednesday, April 6th, in the Connaught Rooms, Great Queen Street, London, W.C.2.

British Patent Specifications

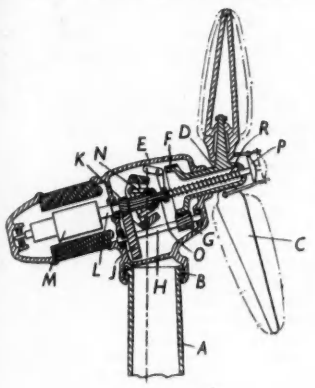
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 2s. 8d. each.

WIND-POWER PLANT

722,978. December 3, 1952.—WIND-POWER PLANT WITH A CENTRIFUGAL GOVERNOR, Allgaier Werkzeugbau G.m.b.H., of Uhingen, Wurtemburg, Germany. (*Inventor: Ulrich Hutter.*)

The invention relates to wind-power plant comprising a vane wheel, an electric generator with speed-increasing gears, and a centrifugal governor driven at generator speed, all enclosed in a casing. As the drawing shows, the plant is mounted on the top of the tower frame *A* through a ball or roller bearing *B*. The casing containing the combined plant is journalled to rotate about a vertical axis. The vane wheel blades *C* rotate about their longitudinal axes. The hollow hub *D* of the vane wheel is journalled in the gear casing and has external teeth *F*, which engage with a pinion *G* on the intermediate shaft *H*, which is parallel to the vane wheel shaft. To this intermediate shaft there is attached a second gear wheel *J*, which drives a pinion *K*, secured to the generator shaft *L*. This shaft carries the armature *M*, and at its end



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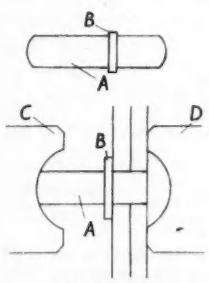
facing the vane wheel drives the centrifugal governor, the fly weights of which are connected to rods *N* and act against the spring retained by a rotating nut which runs free on the control rod *O*. The other end of the control rod is fitted with guide ribs *P*, to which pivoted thrust rod *R* is attached. These ribs act on the vane wheel blades *C* and set them to the starting angle.—*February* 2, 1955.

RIVETING

722,919. February 12, 1952.—HEADLESS RIVETS, Sciaky S.A., 13 to 17, Rue Charles Fourier, Paris, France.

As shown in the drawing, the rivet consists of a cylindrical portion *A* with a shoulder *B*. The ends are rounded to fit the rivet sets *C* and *D*. The shoulder *B* provides a means of holding the rivet in



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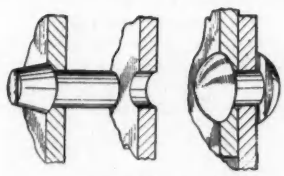
such a position that the mass of metal to be compressed by the rivet sets is similar on either side. To assemble the two plates the stem of the rivet is introduced into the corresponding holes with the shoulder *B* abutting against the top plate. The heads are formed by compression between the rivet sets *C* and *D*.—*February* 2, 1955.

722,010. July 12, 1951.—IMPROVED COLD RIVETING, Rubery Owen and Co., Ltd., Victoria Works, Booth Street, Darlaston, South Staffordshire. (*Inventor: Ernest Coupland.*)

The object of the invention is to provide an improved method of cold riveting when using rivets of mild steel or other alloy which is subject to ageing. As will be clearly seen from the drawing, the length of rod forming the rivet is passed through holes in the two plates to be joined. An upset end formed on the rod is about 1·3 times the diameter of the rod, and the distance of the face from the adjacent end of the rod is equal to the rod diameter. The radius of the formed rivet head shown in the right-hand view is approximately 1·75 times the diameter of the rod. The essence of the invention lies in the fact that both



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of the rivet heads are worked during the riveting operation. It was found that by working both of the rivet heads in this way the difficulty of brittleness, which may cause cracking or breaking away at the stem, is obviated. A further advantage of the method is that both the finished rivet heads tend to have a better peripheral engagement with the riveted plates than in the case of the preformed head of the ordinary mild steel rivet.—*January* 19, 1955.

BEARINGS AND SUPPORTS

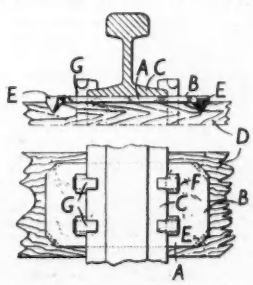
723,562. March 12, 1952.—AN ALUMINIUM ALLOY FOR BEARINGS, Tangyes Ltd., Cornwall Works, Cornwall Road, Smethwick. (*Inventor: Lionel Arthur Reynolds.*)

The invention relates to improvements in alloys for bearings, particularly for the bearings of relatively large slow-speed internal combustion engines wherein heavy firing conditions and minimum lubrication obtains during starting. The invention consists of an alloy, containing by weight between 0·3 per cent and 0·6 per cent magnesium, between 5·0 per cent and 6·5 per cent tin, between 1·0 per cent and 1·3 per cent copper, between 1·5 per cent and 1·7 per cent nickel, the remainder being commercially pure aluminium containing not more than the following percentages by weight of each of the following impurities: 0·5 per cent silicon, 0·6 per cent iron, 0·2 per cent manganese, 0·1 per cent zinc, and 0·1 per cent lead. For bearings running with the softest shafts, such as mild or untreated steel shafts, a casting alloy containing near the maximum tin content and minimum hardening constituents will be found desirable, the silicon content being kept preferably below 0·2 per cent and the magnesium content to the lower limit of 0·3 per cent. For harder shafts—say, above 350 Brinell hardness—it will be found desirable to use a cast alloy containing near the maximum limit of the hardening constituents and, if the initial bedding-in is good, near the minimum tin content.—*February* 9, 1955.

RAILWAY ENGINEERING

723,388. September 23, 1952.—RAIL FASTENINGS, Guest, Keen and Nettlefolds (Midlands), Ltd., London Works, Smethwick. (*Inventor: William Augustus Jenkins.*)

The object of the invention is to provide an improved form of base plate which is particularly, though not exclusively, applicable for use on light railway tracks such as those in mines. As the drawing shows, the base plate *A* is of substantially flat form and is conveniently formed as a rectangular mild steel pressing. The length of the plate is such that when placed in position under a rail it has a part *B* lying on each side of the bottom rail flange *C*. The plate is somewhat narrower than the average rail sleeper shown at *D*. At each



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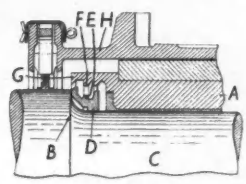
corner the plate is bent at right angles or substantially at right angles so as to form a pointed clawlike projection *E*. The outer face of each projection is machined to provide a substantially flat surface and point the projections. When the plate is placed in position these claws are driven into the sleeper to assist in maintaining the plate in position. The plate is also provided with a suitable number of holes *F* through which may be passed rail spikes *G*. The projecting claws *E* due to their being positioned in the sleeper on the outside of lines joining the holes for the spikes, assist in preventing the sleeper from being split along the grain in the direction of lines joining these holes when the spikes are driven home. Further, the holes are positioned so that the spikes are guided into position in close engagement with the rail, thus maintaining the rail securely in position and preventing the spikes from being bent back. A modified construction is also shown in the specification.—*February* 9, 1955.

723,516. April 22, 1952.—AXLEBOXES FOR RAILWAY VEHICLES, Societe Generale Isothermos, 35, rue de La Tour d'Auvergne, Paris.

The essential purpose of the invention is to provide a device whereby the axlebox can be sealed against oil leaks. As shown in the drawing, between the edge of the bearing *A* and the fixing shoulder *B* of the shaft *C* there is secured a ring *D* consisting of one or more elements and having a profile *E* associated with frusto-conical ribs *F* on the inner face of a skirt-like extension *G* of the bearing which surrounds the



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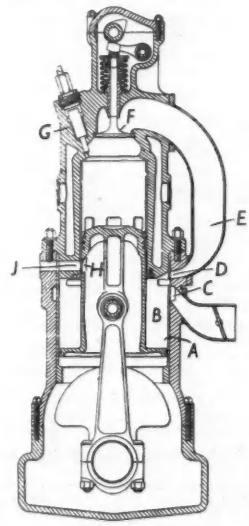
ring. Any oil escaping between the bearing and shaft cannot be projected to the outside owing to the co-operating indentions *E* and *F*, which return the oil to the inside of the box. It is unnecessary to slope the wall *H* of the axlebox, which registers with the ring *D*, as in the case of axleboxes of the conventional type in which no ring is provided for preventing the oil film formed between the shaft and the bearing from leaking to the outside.—*February* 9, 1955.

INTERNAL COMBUSTION ENGINES

723,324. September 14, 1951.—THE COOLING OF TWO-STROKE ENGINES, Joseph Lambert Jameson, "Brockhamhurst," Betchworth, Surrey.

Referring to the drawing, it will be seen that the cylinder block of the engine has two diameters, of which the larger diameter is provided by a sleeve *A* forming a sleeve valve; a piston having two diameters is mounted to reciprocate in the two diameters of the cylinder. The annular chamber *B* above the large diameter of the piston has an air inlet port *C* and an air delivery port *D* which opens to a transfer



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duct *E* extending to a valve *F* at the outer end of the small end of the cylinder. These two ports are controlled by the sleeve *A*, which is reciprocated so as to time the inlet of air to the annular chamber *B* and the discharge of air compressed in that chamber to the transfer duct *E*. The valve *F* controls the admission of compressed air, which forms scavenging air and charging air, into the engine working cylinder, and is supplied with liquid fuel by an injector *G*. To supply the maximum weight of scavenging and charg-

ing air at low temperature to the working space, the following arrangement is provided. The two-diameter piston is hollow with its interior open to the crankcase. The crankcase is fitted with a valve which is opened during the out-stroke of the piston to permit air to be drawn into the crankcase; the small diameter part of the piston has near its head a port *H*, which registers with a discharge port *J* near the inner end of the small diameter part of the cylinder. The air inlet valve is closed to prevent the air drawn into the crankcase from being discharged as the piston moves on its in-stroke so that the air is trapped and caused to circulate in the crankcase, in the hollow piston and over the outer wall of the chamber *B*, where it is exposed by the large diameter of the piston before being discharged usually direct to atmosphere by the registering of the port *H* with the port *J*. By this means the efficient cooling of the crankcase, the wall of the cylinder defining the air compression cylinder *B*, and the entire wall of the two-diameter piston, is achieved. The scavenging and charging air, which is supplied via the port *C*, may be from a compressor, and is not unduly heated by contact with those walls, so that the maximum weight of air, at a relatively low temperature, can be supplied to the working space of the engine.—*February* 9, 1955.

Catalogues

LAURENCE SCOTT AND ELECTROMOTORS, Ltd., Norwich.—Publication number 132, "Marine Type A.C. Motors."

SANDERSON BROTHERS AND NEWBOULD, Ltd., Newhall Road, Sheffield.—Leaflet M.E.32. Saben Tenco butt-welded tools.

SPECTRA CHEMICALS, Ltd., Spectra Works, High Street, Caterham, Surrey.—Leaflet covering Spectra-Color colour layout.

THE MORGAN CRUCIBLE COMPANY, Ltd., Battersea Church Road, London, S.W.11.—Leaflet on refractory strainer cores.

THE WOLSELEY SHEEP SHEARING MACHINE COMPANY, Ltd., Wolseley Works, Electric Avenue, Witton, Birmingham, 6.—Booklet describing Wolseley electric fencing for sheep.

NORTHEY ROTARY COMPRESSORS, Ltd., 200/202, Alder Road, Parkstone, Dorset.—Folder containing descriptive literature covering the company's range of "oil-free" compressors and vacuum pumps.

BLAW KNOX, Ltd., 94, Brompton Road, London, S.W.3.—New literature: Publication BK-180/1, "BK-Fifty" Face Shovel, superseding Publication BK-180; Publication BK-181/1, "BK-Fifty" Drag Shovel, superseding Publication BK-181; Publication BK-182, "BK-Fifty" Dragline; Publication BK-209, "BK-Fifty" Skimmer; Publication BK-213, "BK-Fifty" Grabbing and Lifting Crane; Publication BK-211, "BK-Fifty" Piledriver.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

BRITISH INSTITUTION OF RADIO ENGINEERS

Thurs., March 17*th.*—SCOTTISH SECTION: Department of Natural Philosophy, The University, Edinburgh, Symposium of Three Short Papers, 7 p.m.

CHADWICK PUBLIC LECTURES

Tues., March 15*th.*—Royal Society of Tropical Medicine and Hygiene, 26, Portland Place, London, W.1, "Silicosis," E. J. King, 5.30 p.m.

CHEMICAL SOCIETY

Thurs., March 17*th.*—Burlington House, Piccadilly, London, W.1, "Some Problems in the Chemistry of the Hemicelluloses," E. L. Hirst, 7.30 p.m.

DIESEL ENGINE USERS ASSOCIATION

Thurs., March 17*th.*—Caxton Hall, Westminster, London, S.W.1, "Fundamentals of Free Piston Engines and Their Applications," Clive O. B. Beale and Evelyn S. L. Beale, 2.30 p.m.

ENGINEERS' GUILD

Thurs., March 17*th.*—Caxton Hall, Westminster, London, S.W.1, "Alpine Railway Engineering," Cecil J. Allen, 6 p.m.

ILLUMINATING ENGINEERING SOCIETY

Wed., March 16*th.*—LANCASHIRE GROUP: N.W. Electricity Board, 19, Friargate, Preston, "Simple Measurement of Radiant Energy and the Calibration of Light Sources," H. W. Cumming, 7.15 p.m.——TEES-SIDE GROUP: Cleveland Scientific and Technical Institute, Corporation Road, Middlesbrough, "Studies in Interior Lighting," J. M. Waldram, 6.30 p.m.

INCORPORATED PLANT ENGINEERS

Mon., March 14*th.*—MERSEYSIDE AND N. WALES BRANCH: Royal Institution, Colquitt Street, Liverpool, Annual General Meeting, 7.15 p.m.

Tues., March 15*th.*—MANCHESTER BRANCH: Engineers' Club, Albert Square, Manchester, Annual General Meeting, 7.15 p.m.——S. WALES BRANCH: S. Wales Engineering Institute, Park Place, Cardiff, "Oil Firing Installations," 7.15 p.m.

Wed., March 16*th.*—KENT BRANCH: Bull Hotel, Rochester, "Industrial Lighting," J. F. Roper, 7 p.m.——WESTERN BRANCH: Grand Hotel, Bristol, Annual General Meeting, followed by Films, 7.15 p.m.

Thurs., March 17*th.*—PETERBOROUGH BRANCH: Campbell Hotel, Bridge Street, Peterborough, Annual General Meeting, 7.30 p.m.

Fri., March 18*th.*—BIRMINGHAM BRANCH: MOBILE PLANT DISCUSSION GROUP: Imperial Hotel, Temple Street, Birmingham, "Soil Stabilisation," E. McKenzie Taylor, 7.30 p.m.

INSTITUTE OF BRITISH FOUNDRYMEN

Sat., March 12*th.*—E. MIDLANDS BRANCH: College of Commerce and Technology, Leicester, "An Approach to Foundry Mechanical Handling," C. M. G. Wallwork, 6 p.m.——SCOTTISH BRANCH: Royal Technical College, Glasgow, "Technical Control in a Mechanised Bronze Foundry," W. T. Watt, 2.45 p.m.

Tues., March 15*th.*—COVENTRY SECTION: Technical College, Coventry, "Foundry Work for Diesel Engine Castings," Film and Talk by H. Haynes, 7.30 p.m.

INSTITUTE OF FUEL

Mon., March 14*th.*—N.E. SECTION: Chemistry Lecture Theatre, King's College, Newcastle upon Tyne, "Wind and Solar Energy," P. A. Sheppard, 6.30 p.m.

Tues., March 15*th.*—MIDLAND SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, 3, "Selection and Use of Fuels in a Modern Engineering Heat-Treatment Department," H. Oxley, 6 p.m.

Wed., March 16*th.*—YORKSHIRE SECTION: Royal Victoria Station Hotel, Sheffield, "Smoke and the Law," A. Marsh, 2.30 p.m.

Fri., March 18*th.*—E. MIDLAND SECTION: The College, Loughborough, "Application of Gas Turbines to Industry," 7.15 p.m.

INSTITUTE OF METALS

Mon., March 14*th.*—SCOTTISH LOCAL SECTION: Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2, "Post-War Light Alloy Production," F. Kasz, Annual General Meeting, 6.30 p.m.

INSTITUTE OF PHYSICS

To-day, March 11*th.*—NON-DESTRUCTIVE TESTING GROUP: 47, Belgrave Square, London, S.W.1, "Experiences in Teaching Non-Destructive Testing Techniques," H. A. Maccoll, 6.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Wed., March 16*th.*—N.W. CENTRE: Adelphi Hotel, Liverpool, "The Application of Planetary Gears in Axle Design," 7.30 p.m.

Thurs., March 17*th.*—LONDON CENTRE: Royal Society of Arts, John Adam Street, London, W.C.2, "Some Aspects of Vehicle Insurance and Accident Assessment," 6.30 p.m.——YORKSHIRE CENTRE: Hotel Metropole, King Street, Leeds, 1, "Recent Development in Piston and Piston Ring Design," J. Hepworth, 7.30 p.m.

INSTITUTE OF WELDING

To-day, March 11*th.*—EAST MIDLANDS BRANCH: Technical College, Lincoln, "The Economics of Welding," H. Martin, 7.15 p.m.

Tues., March 15*th.*—LIVERPOOL BRANCH: College of Technology, Byrom Street, Liverpool, "Welding and Motor-Cars," M. H. Lummus, 7.15 p.m.

Wed., March 16*th.*—W. OF SCOTLAND BRANCH: Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2, "Basic Welding Metallurgy," W. I. Pumphrey, 7 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

Tues., March 15*th.*—Geological Society, Burlington House, London, W.1, "Correlations for Use in Transport of Aqueous Suspensions of Fine Solids Through Pipes," K. E. Spells; "Experiments on the Flow of Sand-Water Slurries in Horizontal Pipes," R. A. Smith; "Hydraulic Conveying," C. J. Richardson, 5.30 p.m.

Wed., March 16*th.*—N.W. BRANCH: College of Technology, Manchester, "Instrumentation of a Nuclear Power Plant," P. V. Koller, 7 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., March 15*th.*—Great George Street, Westminster, London, S.W.1, "Geophysical Methods of Exploration and their Application to Civil Engineering Problems," Jack Robertshaw and P. D. Brown, 5.30 p.m.

Wed., March 16*th.*—N.W. ASSOCIATION: 9, The Temple, 24, Dale Street, Liverpool, "Peace-Time Activity of the Corps of Royal Engineers," A. N. Anstruther, 6 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Mon., March 14*th.*—LONDON STUDENTS' SECTION: Institution of Civil Engineers, Great George Street, Westminster, London, S.W.1, "Air Transportation," Sir Miles Thomas, 6.30 p.m.

Tues., March 15*th.*—MEASUREMENTS SECTION: Savoy Place, London, W.C.2, "The Mechanism of Sub-Harmonic Generation in a Feedback System," J. C. West and J. L. Douce, "The Transient Behaviour of Remote-Position-Control Systems with a Hand Spring Non-Linear Characteristic," J. C. West and P. N. Nikiforuk, 5.30 p.m.——S.E. SCOTLAND SUB CENTRE: Carlton Hotel, North Bridge, Edinburgh, "The Genesis of the Thermionic Valve," G. W. O. Howe; "Thermionic Devices from the Development of the Triode up to 1939," Sir Edward Appleton; "Developments in Thermionic Devices since 1939," J. Thomson, 6.30 p.m.——N. MIDLAND CENTRE: Technical College, Bradford, "Colour Television," G. N. Patchett, 6.30 p.m.

Wed., March 16*th.*—SUPPLY SECTION: Savoy Place, London, W.C.2, "An Examination of High-Voltage D.C. Testing Applied to Large Stator Windings," R. T. Rushall and J. S. Simons, 5.30 p.m.

Thurs., March 17*th.*—UTILIZATION AND SUPPLY SECTIONS: Savoy Place, London, W.C.2, "The Standardisation of Retail Electricity Tariffs," A. O. Johnson and N. F. Marsh, 5.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, March 11*th.*—AUTOMOBILE DIVISION GENERAL MEETING: 1, Birdcage Walk, London, S.W.1, James Clayton Lecture, "Heavy-Duty Truck Developments in the United States of America," Robert Cass, 5.30 p.m.——SCOTTISH BRANCH: Technical College, Dundee, "The Development and Scope of Work Study," R. M. Currie, 7.30 p.m.

Mon., March 14*th.*—WESTERN BRANCH: Grand Hotel, Bristol, "Heavy-Duty Truck Developments in the United States of America," Robert Cass, 7 p.m.——E. MIDLANDS GRADUATES' SECTION: Technical College, Lincoln, "Light Aeroplane Design," A. W. J. Smith, 7.15 p.m.——LONDON GRADUATES' SECTION: Institution of Civil Engineers, Great George Street, Westminster, London, S.W.1, "Air Transportation," Sir Miles Thomas, 6.30 p.m.

Tues., March 15*th.*—INTERNAL COMBUSTION ENGINE GROUP DISCUSSION: 1, Birdcage Walk, Westminster, London, S.W.1, "The Performance of Pressure Chargers and Scavenge Pumps for Internal Combustion Engines," 6.45 p.m.

Wed., March 16*th.*—E. MIDLANDS BRANCH: County Technical College, Newark-on-Trent, "The Production of a Technical Journal," B. W. Pendred, 7.30 p.m.——SCOTTISH BRANCH: Technical College, Dundee, "The Development and Soppe of Work Study," R. M. Currie, 7.30 p.m.——SOUTHERN BRANCH: Polygon Hotel, Southampton, "Some Problems Associated with the Manufacture of Large Turbo-Alternators," J. Henderson and J. Taylor, 7.15 p.m.——S. WALES BRANCH: S. Wales Institute of Engineers, Cardiff, "Some Very Light Alloys for the Engineer," W. R. D. Jones, 6 p.m.——N.E., A.D. CENTRE: Chemistry Lecture Theatre, The University, Leeds, "Analysis and Interpretation of Service Records," A. T. Wilford, 7.15 p.m.

Thurs., March 17*th.*—MIDLAND BRANCH AND A.D. CENTRE: James Watt Memorial Institute, Great Charles Street, Birmingham, "Heavy-Duty Truck Developments in the United States of America," Robert Cass, 6 p.m.——SCOTTISH BRANCH: Royal Technical College, George Street, Glasgow, "The Development and Scope of Work Study," R. M. Currie, 7.30 p.m.——YORKSHIRE BRANCH: Chemistry Lecture Theatre, The University, Leeds, "Rocket Propulsion," A. D. Baxter, 6.30 p.m.——WESTERN GRADUATES' SECTION: Grand Hotel, Bristol, "Some Post-War Aspects of Combustion Research," S. K. Powell, 7.15 p.m.

Fri., March 18*th.*—1, Birdcage Walk, Westminster, London, S.W.1, Annual General Meeting, 5.30 p.m.——N.W. BRANCH and N.W., A.D. Centre: Lesser Hall, Peter Street, Manchester, "Heavy-Duty Truck Developments in the United States of America," Robert Cass, 6.45 p.m.——E. MIDLANDS GRADUATES' SECTION: Midland Hotel, Derby, "The Professional Engineer in Management," D. H. Bramley, 7.15 p.m.

INSTITUTION OF MINING AND METALLURGY

Thurs., March 17*th.*—Geological Society of London, Burlington House, Piccadilly, London, W.1, "The Geology of the Roan Antelope Orebody," J. J. Brummer; "Handling Ore and Waste at Irwin Shaft, Roan Antelope Copper Mine," J. H. Sinclair, 5 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

To-day, March 11*th.*—EASTERN COUNTIES BRANCH: Diocesan Hall, Tower Street, Ipswich, "Symposium on Production Engineering Subjects," Annual General Meeting, 7 p.m.

Mon., March 14*th.*—DERBY SECTION: College of Art, Green Lane, Derby, Annual General Meeting followed by Films, 7 p.m.——SHEFFIELD AND YORKSHIRE SECTIONS: Grand Hotel, Sheffield, "The Practical Application of Production Engineering Research," D. F. Galloway, 6.30 p.m.

Wed., March 16*th.*—BIRMINGHAM SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, Annual General Meeting and Chairman's Address, 7 p.m.——LIVERPOOL SECTION: Exchange Hotel, Liverpool, "Electronics as an Aid to Production," H. A. Thomas, 7.30 p.m.——NORWICH SECTION: Assembly House, Theatre Street, Norwich, Annual General Meeting and Film Show, 7 p.m.——SOUTHERN SECTION: Polygon Hotel, Southampton, "Some Problems Associated with the Manufacture of Large Steam Turbo-Alternators," J. Henderson and J. W. Taylor, 7.15 p.m.——S. ESSEX SECTION: Ilford Bowling Club, Nr. Ilford Station, Ilford, Annual General Meeting and Film, 7.30 p.m.

Thurs., March 17*th.*—CORNWALL SECTION: Trevensen, Pool, Redruth, "The Effective Use of Materials," F. Nixon, 7.15 p.m.——GLASGOW SECTION: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2, "The Control of Quality in Medium Quantity Production," J. Loxham, 7.30 p.m.

Fri., March 18*th.*—LIVERPOOL GRADUATE SECTION: Stork Hotel, Liverpool, Annual General Meeting, 7.45 p.m.——STOKE-ON-TRENT SECTION: Town Hall, Hanley, Stoke-on-Trent, "Management and Production," H. Bainbridge, 7.45 p.m.——WEST WALES SECTION: Central Library, Alexandra Road, Swansea, "Work Measurement," J. A. Lamond, 7.30 p.m.

INSTITUTION OF THE RUBBER INDUSTRY

Mon., March 14*th.*—MIDLAND SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, "Abraded Tyre Treads," V. E. Gough, 6.45 p.m.——PRESTON SECTION: Bull and Royal Hotel, Church Street, Preston, "Inventions Still Needed to Provide Better Operation Control of Rubber Manufacture," H. C. Young, 7.15 p.m.

Mon., March 21*st.*—MANCHESTER SECTION: Engineers' Club, Albert Square, Manchester, "Ozone Resistance of Butyl Vulcanisates," D. C. Edwards and E. B. Storey, 6.45 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, March 11*th.*—ORDINARY MEETING: Pepys House, 14, Rochester Row, London, S.W.1, "The Rolling of Structural Sections," W. H. Bailey, 7 p.m.

Mon., March 14*th.*—SHEFFIELD AND DISTRICT SECTION: Livesey Clegg House, Sheffield, "The Reconstruction of a Soaking Pit Building," K. H. Best, 7.30 p.m.

Fri., March 18*th.*—INFORMAL MEETING: Pepys House, 14, Rochester Row, London, S.W.1, "Some Notes on the Flow of Fluids," R. F. Twist, 7 p.m.

MANCHESTER GEOLOGICAL AND MINING SOCIETY

Thurs., March 17*th.*—Mining and Technical College, Wigan, "Skip Winding," J. G. Belfitt and J. Birch, 3.15 p.m.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

To-day, March 11*th.*—Mining Institute, Newcastle upon Tyne, "A Comparison of the Total Weight and Bulk of In-Line Naval Gas Turbine Engines of Differing Degrees of Complexity," D. F. Collins and D. W. Thomas, 6.15 p.m.

OLD CENTRALIANS

Mon., March 14*th.*—Chez Auguste Restaurant, 47, Frith Street, London, W.1, "Rudyard Kipling and the Engineers," T. C. Angus, 12.45 p.m.

REINFORCED CONCRETE ASSOCIATION

Tues., March 15*th.*—MIDLAND COUNTIES BRANCH: Birmingham and Midland Institute, Paradise Street, Birmingham, "Reinforced Concrete in Coast Protection Works," J. A. Lewis, 6 p.m.

Wed., March 16*th.*—11, Upper Belgrave Street, London, S.W.1, "The Gifford-Udall-C.C.L. System and Recent Developments in Prestressed Concrete," E. W. H. Gifford, 6 p.m.

ROYAL AERONAUTICAL SOCIETY

Tues., March 15*th.*—SECTION LECTURE: 4, Hamilton Place, London, W.1, "The Production of Large Forgings," C. Smith and J. Crowther, 7 p.m.

Thurs., March 17*th.*—EIGHTH LOUIS BLERIOT LECTURE: Institution of Mechanical Engineers, 1, Birdcage Walk, London, S.W.1, "Making Aeroplanes Independent of Runways," Georges Hereil, 6 p.m.

ROYAL SOCIETY OF ARTS

Mon., March 14*th.*—CANTOR LECTURE: John Adam Street, Adelphi, London, W.C.2, "The Mechanical Properties of Metals: Tensile Properties," Hugh Ford, 6 p.m.

SOCIETY OF CHEMICAL INDUSTRY

Fri., March 18*th.*—CORROSION GROUP AND THE LIVERPOOL SECTION: Chemistry Lecture Theatre, The University, Liverpool, "Control of Corrosion in Boilers," P. Hamer, 7 p.m.

SOCIETY FOR WATER TREATMENT AND EXAMINATION

Fri., March 18*th.*—Metropolitan Water Board, Rosebery Avenue, London, E.C.1, "The Standardisation and Selection of Bile Salts and Peptone for Culture Media Used in the Bacteriological Examination of Water," N. P. Burman; "The Rapid Micro-Estimation of the Major Anions in Fresh Water," F. J. H. Mackereth; "Fluoridisation of Domestic Water Supplies: Assessment and Maintenance of the Dose to be Applied," J. Longwell, 9.30 a.m.

WOMEN'S ENGINEERING SOCIETY

Wed., March 16*th.*—MANCHESTER BRANCH: Engineers' Club, Albert Square, Manchester, "Refrigeration," J. S. Porter, 6.45 p.m.